CHAPTER

29

Written and Oral Communication

WHAT YOU WILL LEARN

- High-quality written and oral communication is essential in all fields of endeavor, including the chemical process industry.

Throughout your career as an engineer, chances are that you will draw on your skills in oral and written communication far more often than you ever imagined. Engineers report that they spend most of their time using some combination of the four communication skills: writing, speaking, reading, and listening [1]. The situation is the same for most engineering students, although their education is apt to have given them far more opportunity to read and to listen than to write and to speak.

Technical writing and oral presentation skills are particularly important to the design engineer. After all, the final product of a design project is generally an oral or written report (and sometimes both). Furthermore, throughout the design process, engineers use feasibility studies, environmental impact reports, meeting minutes, progress reports, status reports, appropriation requests, design notebooks, equipment specification sheets, and personnel evaluations, as well as various letters and memos, to document their work and to communicate their findings to colleagues, company management, clients or potential clients, and possibly the general public.

Any evaluation of your success as an engineer, then, will be based in whole or in large part on the quality of your written and oral communication.

In this chapter, instruction in basic writing skills is not attempted. There are many good texts on technical communication [2–4]. However, guidance in adapting this skill to the area of engineering communication that focuses on process design is provided. The formats and guidelines for written and oral design reports are explained, and strategies for improving one's communication are given. Other types of written reports common in engineering, such as laboratory reports and technical journal articles, are not covered. Many of the same strategies, however, apply to these genres, even though the specific guidelines may not.

A sample student design report and the visuals from the oral presentation of the project are given in Chapter 30 of this book. Also included is a critique of these reports. Examples of the problems described in this chapter are given in the sample report.

29.1 AUDIENCE ANALYSIS

In all engineering communication, a crucial step is **audience analysis**. Written or oral reporting is, by definition, a transfer of information. One's success at this transfer hinges on presenting the type, detail, and scope of information that the audience expects with a clarity that avoids misunderstandings. It is important that you do the following:

1. **Identify Your Intended Audience:** Will your report or oral presentation be for fellow chemical engineers, other engineers, managers, executives, clients, or the general public? Both the appropriate level of detail and the focus will vary with the background of the audience. Senior executives, even if they were trained years ago as chemical engineers, may not quickly understand the mathematical details of your design. More important, they will not be very interested. Rather, they need more of a big-picture focus. How might what you have done impact the bottom line? The public's perception of the company? The long-term viability of your company's technical advantage over its competitors? There may be a broad range of audience backgrounds, especially if the primary recipients of your report forward it to others.
2. **Determine What Response You Want from Your Audience:** Do you want them to approve the project? Do you want them to abandon the project? Do you want them to leave the presentation or finish reading the report confident that you have presented the best alternatives in a way that will help them make the decision? Do you want them to order the correct equipment and materials? Do you want them to be confident that you have studied the most important environmental impacts of the project? Do you want to be certain that your safety recommendations are immediately accepted and implemented?
3. **Imagine Yourself to Be One of Your Audience:** After writing the first draft, read the report as if you were one of the people identified in Step 1, with the indicated background and areas of concern. Read the report or hear the oral presentation as this person would, and imagine what response you would have. What would you do after reading or hearing the report?
4. **Iterate:** Multiple drafts are essential. As is the case when solving any complex problem, one must attempt a solution, evaluate it, and then improve upon it. In succeeding drafts, reconsider your likely audience response. If it is not what you want, you must continue to revise.

29.2 WRITTEN COMMUNICATION

Some of the purposes of putting ideas into writing are

1. To provide a permanent record
2. To get someone to do something (action writing)
3. To instruct someone (informative writing)

Often in engineering writing, all three purposes apply. What you write is a permanent record of your analysis, your conclusions, and your recommendations. Unlike oral communication, written documents must stand on their own, because the author is generally not present to answer questions about the content. Also, these documents will be referred to more than once, often much later than when they were written. Precise wording is crucial, because decisions will often be made by the reader without any further consultation with the writer. Ambiguous words or phrases, gaps in logical developments, and undocumented assumptions can lead the reader to make a wrong decision.

To help both the writer and the reader, various formats are used in written engineering communications. They serve both as a guide for the information flow of the document and as a rough checklist to be sure that important content is not omitted. The reader anticipates the location of specific content within the document; thus, the format helps the reader to understand the document, as well as to skip to those sections of most importance when pressed for time. In the following sections, several formats common to chemical process design are described. The detailed guidelines for each format vary from organization to organization, and a sample format for design reports used at West Virginia University is given in section 29.2.8.

Although a typical set of guidelines is given, it is by no means the only (or necessarily the best) such set for design reports. In fact, the best guidelines in a particular organization are the ones agreed to by that organization. They are, in the best of circumstances, an agreement between both parties, whose purpose is to make the communication between the writer and the reader more complete, reliable, and efficient. The first step, then, is to determine what your organization's guidelines are.

29.2.1 Design Reports

In general, a **design report** presents the results of a design effort to those who will either implement the design or decide whether the design will be implemented. As with the design process itself (described in Chapter 2), design reports are of varying scope, detail, and complexity. Early on, the order-of-magnitude estimate leads to a relatively short report whose purpose is to persuade the reader either to commit to go forward to the study-estimate stage or to abandon the project in favor of other opportunities. The audience for such a report is typically upper management.

The goal of these early reports is to present the data required for decisions that are quite difficult to make. When the final project may require a capital expenditure of millions or even hundreds of millions of dollars, the stakes are high, and the audience needs enough information to be reasonably confident that the decision is the right one. The audience requires the following:

- A careful analysis of a base case with sufficient detail to provide a context
- Evidence that the most reasonable options have been considered

- A careful analysis of these options
- A statement of and justification for any significant assumptions made
- A finite number of options, with a clear analysis of the advantages and disadvantages
- An estimate of the accuracy of the analysis

The audience for such a report is likely to be less interested in the details of proven technology than in the details and risks of new processes, catalysts, or equipment. The financial, environmental, health, and public perception aspects are likely to be of high concern.

Later design reports (based on preliminary design, definitive, and detailed estimates) are apt to have more technical audiences of process engineers, engineering managers, project engineers, purchasing agents, and so on. They will be more interested in the details that allow the design to proceed to a final, constructed, and operating plant. One outcome of any successful design report, however, is the informed decision of the readers to do something—to commit the company to more detailed design (or not), to order equipment, to start up a plant, to go after new markets, or to modify a process to increase yield or reduce environmental impact.

29.2.2 Transmittal Letters or Memos

The report stands on its own, but it is usually sent to the readers with a cover sheet giving a broad overview of the document. This is a memo if the recipient is a fellow employee of your organization; it is a letter if the recipient is a client or an employee of a different organization. Some engineers may mistakenly treat this transmittal memo or letter as merely a tag formally indicating who is doing the transmitting, when, and to whom. However, the real purpose and distinct value of this sheet is to convince the potential reader to become a bona fide reader. To do this, the transmittal memo must contain a very brief statement of the scope and of the most important conclusion or recommendation of the report. It must catch the attention of the recipient. The reward of a good transmittal memo is that your report is read (at least in part).

29.2.3 Executive Summaries and Abstracts

Design reports can be long, and they often must contain very detailed information that will be of interest to only a small fraction of the readers of the document. All readers, however, benefit from a broad overview of the project being reported, with key assumptions, results, conclusions, and recommendations given. This overview is called an **executive summary**. Its length is governed by the guidelines of the organization. Some companies impose a one- or two-page maximum, whereas some organizations (especially government agencies) encourage longer executive summaries that are, in effect, short reports. Some guidelines suggest that the executive summary should be no more than 5% or 10% of the length of the report. The key is to remember that a well-written executive summary will be short enough that busy executives will read it all but will communicate enough information to satisfy these executives, who are unlikely to read the rest of the report.

Some guidelines fail to make the distinction between an executive summary and an abstract. Others define the executive summary as longer than an abstract or more focused on conclusions and recommendations than is the abstract, which may also summarize the procedures used in the analysis. In any case, the executive summary must be focused on the needs of executives whose job is to make the proper decision based on the work you have done, without reading the details contained in the full report. On the other hand, an **abstract** is a very boiled-down version of the complete report and should have the same focus as does the full report. The abstract provides enough information for the reader to decide whether to read the report, and it provides an overview that will help the reader to assimilate the information while reading the report. Even though an abstract or executive summary appears at the beginning of the report, it should be written last. Care should be taken when writing the executive summary and/or abstract that all important results and conclusions are included, because these are often the only sections of the report that are read in their entirety.

An executive summary (or abstract) should be a synopsis of the project being reported, not a description of the report itself. The former is called an **informative executive summary** and may include statements such as, "The total capital investment is $100 million." The latter would be a **descriptive executive summary** and would include less helpful statements such as, "The total capital investment is given in Section 4 of the report." If the goal of the summary is to get information to a reader whose time is too valuable to read the report (but who must make an important decision), it is poor strategy to write an executive summary (descriptive) to convince readers that they must then read the report to get any useful information. Rather, the executive summary (informative) should contain all the information necessary for the executive reader to make the decision, and the body of the report should contain the details that will be required by others to implement the decision.

29.2.4 Other Types of Written Communication

Progress reports are often required for long projects. The goals of these (usually short) reports are

1. To indicate the progress made to date
2. To present a schedule for the remainder of the project
3. To explain any unanticipated problems or opportunities encountered
4. To propose or to report on changes in direction from those originally projected
5. To give a synopsis of the important findings of the project

Performance evaluations are periodic (often annual or semiannual) reports of the quality of an employee's work. They generally include

1. A synopsis of the completed work
2. An evaluation of the quality of that work
3. A list or narrative of the observed strengths and weaknesses
4. Recommendations for improvement
5. Qualitative or quantitative rankings on specific work attributes

Minutes are often taken during design meetings, especially when important decisions are made or when the meetings involve clients. The minutes include a list of important topics discussed, important decisions made, and crucial information communicated to the parties present, as well as the list of attendees and the time and place of the meeting. Without minutes, different attendees will have memories (or even will have notes) of the decisions made that are in conflict. Minutes create the permanent record of the meeting that allows everyone involved to know where things are headed. To be effective, they must be signed by the minutes author and by representatives of each of the groups at the meeting. This typically involves a total of three signatures (client, manager, and author).

Increasingly, **e-mail** within an organization and across the Internet is the medium of choice for rapid communication. Unfortunately, some engineers (and others) fail to apply the same criteria for precision, clarity, and accuracy to e-mail messages that they do to other written communication. These messages can be extremely important, and, although they can be less formal, they must convey the message accurately. Also, some e-mail users forget that their messages are at least as permanent as a paper document. In fact, many more copies may stay around for much longer. In some organizations now, there is a rule that one should not put anything in an e-mail message that one would not want circulated in hard copy throughout the organization (or even outside). Also, any document put on the Internet is potentially available to anyone in the world.

29.2.5 Exhibits (Figures and Tables)

Many of your important results will be presented in figures and tables. When the numerical values are important to the audience, a table is more appropriate. When the trend of the data or the difference between sets of data is important, a graph is better. Figures (graphs and pictures) are numbered sequentially in the order that they are cited in the report. If they are not cited, they are not included. Similarly, tables are numbered sequentially in the order that they are cited. In most reports, these exhibits appear close to the point where they are cited, but care should be taken not to interrupt the flow of the text too much.

The typical kind of graph that engineers use (with two linear scales) is sometimes called a **scatter plot** or an ***x-y* plot**. Care should be taken to choose properly the dependent and independent variables, and the axes must be labeled with the variable name. Usually, an axis is not labeled with the symbol for the variable (because these are not standardized), and it is never labeled with only the units of the variable. The units should be included in the axis label after the variable name. For example, "Manufacturing Cost ($/y)" would be appropriate, but "($/y)" would not. The title of the graph appears at the bottom of the figure, immediately after the figure number. The title should be descriptive and should not merely repeat the axis labels. For example, "Figure 3. Determination of Optimum Pipe Diameter" might be appropriate, whereas "Figure 3. Annualized Cost Versus Pipe Diameter" would not be acceptable.

Other types of figures used in design reports are process (and block) flow diagrams, piping and instrumentation diagrams, pie charts, histograms (bar charts), and scheduling charts. Each is numbered, cited in the text, and titled. Specific format instructions for flow diagrams and P&IDs are given in Chapter 1. Pie charts and histograms are used to show relative sizes of quantities. For example, the total operating cost has many components, but only the steam cost may be a significant fraction compared with the rest. A pie chart would show this. (Also, the total quantity that the pie represents should always be given.) Relationships between numerical variables, however, are not shown on pie charts or histograms. A scheduling chart is often included in reports of ongoing projects, and these are numbered, titled, and located in the same way as other figures.

Tables contain a number and descriptive title at the top, and each column (except the first in some cases) has a label with appropriate units. Appropriate numbers of significant digits should be shown, and the columns of numbers should line up by their decimal points.

29.2.6 References

When one uses the ideas or words of another author, proper attribution is made in the report. A mark (superscript number, number in brackets, or author name and date in parentheses) is shown in the text at the point where the work is used. The complete citation is given either in a footnote at the bottom of the page or at the end of the body of the report in a separate section. The format for the text mark and for the citation are set in the guidelines of the organization and must be followed.

There are two main reasons for citations of other work. The citation acknowledges the ideas as someone else's, not yours. Such acknowledgment is essential; its absence is plagiarism. (Note that citation is required even when there is no direct quotation of another author.) Also, the citations give the reader guidance to other written sources whose level of detail or focus are different from your report.

With the Internet, it is easy to download text into a file on your computer. To cite this material properly in your report, you must be sure to keep enough authorship data in the file to be able to write the citation. At a minimum, you should include the Internet address (URL) so that you can go back and obtain the author, date, and other information.

29.2.7 Strategies for Writing

The writing process is different for each writer. Some people write best long-hand, others at a computer. Isolation is better for some, but being in the middle of the activity is better for others. Some prefer to spend more time per draft on fewer drafts, whereas others need to get something down on paper (screen), even if it will be modified drastically before the final draft. Here is a strategy that can be quite effective:

1. Define your audience and your purpose.
2. Outline what you want in the report. This may be formal or only a list of topics, statements, or visuals that are key to your message.
3. Start writing early. Writing the introduction is a way of exploring what the problem is. Once you have identified the problem, the focus of the rest of the report will be clearer. Think of the writing of the report as you would any problem, and use one of the problem-solving strategies from this book.
4. In the first draft, focus on the facts and on the logic. Save editing for later.
5. Do not turn in a first draft as a final draft.
6. Set aside the writing for a day before you pick up the hard copy to revise it.
7. Revise for organization, logic, technical content, clarity, and so on.
8. Set aside the hard copy for a day.
9. Revise for grammar, spelling, punctuation, conciseness, word choice, and other elements of editing.
10. Have someone read it aloud to you.
11. Do the final revision.
12. Proofread the hard copy.

This strategy is an example of an ideal process. Other models could be found. We must admit that we do not always follow all these steps, but the more closely we follow them, the better our writing is.

An important issue is writer's block, which is a state of such high anxiety about writing that writing becomes impossible. Much like stage fright, writer's block is autocatalytic. The writing paralysis caused by the anxiety creates increased anxiety, which leads to heightened paralysis. Identifying the cause leads naturally to the cure. The three most common causes are as follows:

1. **Not Fully Understanding What You Are Trying to Explain:** If you are confused about the technical content of your work, it is very difficult to put it down in words.

2. **Having No Clear Sense of Audience or Purpose:** If you do not know who will read your report, how can you communicate with them?
3. **Trying to Turn Out a Final Version Painful Word by Painful Word:** If you want to write the perfect report in one draft, that draft will take far longer than writing multiple drafts.

When a group writes a single report, there are three basic strategies:

1. **Assigned Sections:** This is especially helpful for long reports or when different members of the group have different strengths. A drawback is that the logical connections between the sections can be missed, and this must be corrected by having all members of the group critique all sections of the report between drafts. Finally, one person needs to go through and modify the writing of the sections so that they are written in one style.
2. **Writing by Committee:** On shorter reports, the entire group can meet together, talk about what should be in each section, and decide as a group what the wording should be. This is a difficult strategy to implement, and, in fact, confusing, unfocused writing is often characterized derisively as "written by committee."
3. **Assigned Functions:** Members of the group can be assigned tasks such as preparing the outline, writing the drafts, critiquing the drafts for technical errors, critiquing the drafts for expected audience response, checking for consistency and logical connections, and so on. Again, coordination is the key. Everyone reads all drafts.

29.2.8 WVU Guidelines for Written Design Report

The following guidelines were written by the chemical engineering faculty at West Virginia University and are available at http://www.che.cemr.wvu.edu/publications/projects/index.php. They may be reproduced for use in engineering courses with appropriate attribution to the Web site.

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.

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 semicolons.

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 semicolon and followed by a comma (for example, "A three-compressor configuration was investigated; however, the two-compressor configuration was found to be the optimum").

Semicolons 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 occurs only 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 or 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 necessary only 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 wants still 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 nonroutine or unique computational aspects.

For our junior designs, a subsection 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," such as 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 contain only 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 Contents page 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 versus 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 nonquantitative independent variable is being plotted, *e.g.*, cost (y-axis) versus 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. 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 three-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/y instead of 25 million dollars per year. Include lead zeroes in all numbers less than 1, *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 than 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:

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

For an ideal gas, Equation 1 reduces to:

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

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, nontechnical 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 or not the information is in the report somewhere 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.

29.3 ORAL COMMUNICATION

Public speaking can be scary at first, but oral communication is crucial in engineering design activities. When done well, it communicates information faster than can the written word, and it allows for immediate communication from the audience to the speaker and between members of the audience. Thus, oral presentations (with questions) provide for a type of feedback control on the communication process, whereas written communications are closer to feed-forward control.

The key to effective oral communication is, as it is for written communication, audience analysis. Include visuals that focus the audience attention on the areas of the project analysis that both you and the audience feel are important. Be sure that the audience receives the information required for making the right decision, and be sure not to bore the audience. If the readers of your report get bored, they may come back to it later. If the attention of your listeners starts to drift, the information is lost.

Before the actual presentation, practice is essential. (It may surprise you to learn that most faculty do not practice their lectures.) If possible, practice in front of real audience members who have agreed to give you feedback. Otherwise, try taping (audio or video) your presentation and critiquing it yourself. If none of these techniques will work, go to a quiet room and give your presentation out loud to yourself. In any case, it is best if you use the actual equipment (overhead projector, slide projector, and/or computer) that you will use in the actual presentation. If this is impossible, use hard copies of your visuals.

Successful oral presentation requires a degree of self-confidence. To avoid a last-minute problem in this regard, give your practice talk far enough in advance that you can make corrections to your talk and/or your visuals. If your audience says that you need to make major changes, you need to be able to implement these suggestions.

Even when speakers are well prepared and self-confident, often they are nervous. A variety of techniques can be useful to alleviate tension. Here are a few:

- Prepare notes that you can refer to if you draw a blank on what to say next or to be sure that you talk about the key points. The notes should be on stiff note cards that will be easy to hold still and that will not distract you or the audience.
- Practice the presentation in front of a group. You are likely to be most nervous during the first time that you give a presentation.
- On your note cards, print in bold letters "RELAX" or something else that will be a trigger to help you calm down.
- If you tend to speak too quickly during presentations, print "SLOW DOWN" on a note card.
- Even if you never refer to them, note cards can be a kind of security blanket that could help you relax.
- Look at a point just above the heads of your audience. They will think you are making good eye contact, but you can avoid really seeing them.
- Before the start of the presentation, take a deep breath or two to calm down.
- During the presentation, keep focusing on the remainder of the presentation. If you have made a mistake (by omitting to say something that you wanted to include or by not remembering why you chose the reflux ratio that you did), ignore it until the question-and-answer period at the end. Reminding yourself and your audience that your presentation was less than perfect will make it more so.
- If questions during your talk make you nervous, start your talk by asking that the audience save their questions until the end.
- Before the talk begins, go to the room and check it out. Where will you stand during the talk? Would you feel more comfortable and in control if the projector were moved? (Often it can be.) Do you want the lights high or low? By getting used to the environment and making small changes to it, you begin to feel more in control. In a classroom or conference room, you may be able to move chairs or to keep the front row empty, if that would help.
- Avoid looking at one person in the audience throughout the talk. If that person is interested, he or she will show this by facial expressions, and you will feel good. However, if suddenly that person loses interest, you may be devastated.
- Do not allow yourself to be in a rush immediately before your talk. Sit down, take a short walk, whatever will calm you, but do not get into a serious conversation.
- Do not drink too much coffee or other caffeinated beverages before a talk.
- Be sure the computer is working and can read your PowerPoint file, your transparencies are in order, and the pointer is where you want it before the last minute.

During the question-and-answer period, you relinquish part of your control over the situation. You do not know what will be asked, but you must be prepared to answer. Dealing with this uncertainty requires additional strategies:

- Anticipate what the questions will be. Often, especially if you practice the talk with an audience, many of the questions become obvious. Prepare answers to each of these.

- Admit when you do not know the answer to the question. However, if you have a partial answer, offer that. You should not leave the questioner with the impression that you know nothing about the topic.
- Thank the audience member for the question, even if you do not know the answer. If it is a question that you, too, would like the answer for, tell the audience so. If you will be investigating the issue further, let them know that.
- Do not try to answer the question until you are sure that you know what is being asked. Ask the questioner for clarification if necessary.
- If you need time to think about your answer, restate the question. This not only gives you a few seconds to think, but it also helps to make sure that you are answering the right question.

29.3.1 Formal Oral Presentations

When you are talking to a group (sometimes a large group), the presentation can be quite formal. You may be introduced, and there may be applause after you are finished. In this type of presentation especially, it is important that you have a strong opening and closing and that you focus on keeping the attention of the audience.

Prepare simple, uncluttered visuals that everyone in the room can see. Be sure to see the room before your talk. If the large crowd is going to make you nervous, plan to use the techniques mentioned earlier to make it feel like a smaller audience.

29.3.2 Briefings

Briefings are a very common form of oral presentation, in which a small group of people (as in a conference room) listen to your talk. The size of the audience will mean that audience members are more likely to try to pay attention to your talk than a very large audience would, but you must directly address their needs for information. Again, computer slides or transparencies are usually used, and you should prepare a hard copy set of these for each audience member. Because people more often take notes at a briefing than at a formal oral presentation, the hard copy will help them to focus on your talk. Also, they may find it more helpful to follow your talk by looking at your hard copies rather than at the screen.

Because the audience tends to have a narrow range of background, the briefing tends to be more detailed, and the question period is usually more extensive.

29.3.3 Visual Aids

Most technical presentations are developed around the visuals. Start with a title slide and then a slide that gives the big picture. As with written reports, it is important to obtain the guidelines for oral presentations from your organization. Some are very prescriptive, others not.

A rough guideline is that each visual will be used for one minute; however, this timing varies greatly. Sketch your visuals crudely as you run through what you would like to say. Imagine that you are a typical audience member. Would you have received the right information? Revise your planned visuals to address the gaps or lack of continuity.

A mixture of text visuals and graphics is usually most effective. Tables rarely make good visuals. As you explain the meaning of a trend on a graphic visual, your audience is absorbing the trend itself. When you present your conclusion, a text visual will probably be better. The best way to improve your visuals (in fact, your entire presentation) is to reflect on your own response to the visuals and presentations of others. What kept your attention? What was confusing? What communicated the most high-quality information? Again, doing a dry run with a friendly audience is a good way to get constructive criticism and feedback in a comfortable environment.

Be prepared to point at the screen to direct the audience attention. Before the presentation, the pointer should not only be located, but also tested by the presenter. One must avoid moving the pointer either so fast or so erratically that the audience is distracted. If the presenter is too nervous, it will be difficult to use any pointer without erratic movement. If this is the case, both hands should be used to steady the pointer. If all else fails, the presenter should find a way to avoid using the pointer. In any case, avoid moving the pointer except when it is in use. The audience will always try to follow a moving pointer.

Right-handed people should always position themselves so that the screen is to their right as they face the audience. Left-handed people should always position themselves so that the screen is to their left as they face the audience. This orientation makes it more comfortable to maintain eye contact with the audience when pointing to the screen.

Slides, transparencies, computer projections, and videos can be used for the visual aids. Each has its own advantages, and one should consider all options before deciding how best to present the material. However, there are two common traps to avoid. Using more than one of these media in a presentation can be impressive if done well; it is invariably disastrous if done without a great deal of rehearsal. Also, one must be prepared with a strategy for continuing if the equipment malfunctions; this can occur especially frequently with state-of-the-art computer projection hardware and software.

There are many guidelines concerning the size of lettering and the density of information to use on visuals. However, the best strategy is to imagine what the audience response would be.

No visual should ever be used in a presentation unless it has been previewed with similar equipment, in a similar room, from the most remote position that an audience member can be located.

29.3.4 WVU Oral Presentation Guidelines

The following guidelines were written by the chemical engineering faculty at West Virginia University and are available at http://www.che.cemr.wvu.edu/publications/projects/index.php. They may be reproduced for use in engineering courses with appropriate attribution.

When presenting an oral report it is important to realize that the audience cannot digest material in the same way as they can when reading a report. There will be no time for them to reread a sentence or paragraph, or to study a table or figure. Therefore, it is incumbent upon the speaker to emphasize the important points. The recommendations that follow, though written for any type of oral presentation, are written within the context of a design presentation.

All oral presentations are organized as follows:

1. Tell the audience what you are going to tell them.
2. Make your presentation.
3. Remind the audience what you told them.

With this in mind, here is one way to organize an oral presentation.

Title Page

Identify the report and the presenters on a visual aid.

Outline

Tell the audience what you are going to tell them, and use a visual aid for reinforcement. This is usually an outline of the report. It is not sufficient to list the structure of the report, *i.e.*, introduction, results, discussion, conclusion. You should include a few words abstracting the contents of each section. Note: this visual should not be titled "Agenda."

Early in your talk, describe the project, flowsheet, etc., in general, before the details. Also, early in your talk, mention the "bottom-line" conclusion.

Results

This follows the outline of the results section of a written report described in the document titled *Written Design Reports*. However, there are a few important points to remember. First, a detailed stream flow table will not be easily seen or understood by your audience. Second, what is effectively communicated in a table in a written report might be best communicated orally using a graph or pie chart. Avoid using complex tables and figures with small print. These can neither be seen in the back of the room nor digested by anyone.

All of the rules on figures and tables in the document entitled *Written Design Reports* extend to oral presentations.

Discussion

Once again, the content is similar to that described in the written report section. The only difference is how you choose to communicate your information.

Conclusions

Here you remind your audience what you told them, usually as a list or outline. Remember the bottom line!

Recommendations

This is self-explanatory. If this section and the conclusion section are both short, they can be combined.

Other Important Points When Making an Oral Presentation

PowerPoint Slide Show

If you are considering using fancy background templates, animation, and/or special effects, think again. They are distracting. Use them sparingly, and only if they add to the effectiveness of the presentation. A simple, color background template is recommended. The background template should be removed or covered when showing large figures, particularly PFDs; such figures should be presented with a white background. Finally, it is also recommended that the font size be set differently on each slide so that the slide appears full.

Content of Visuals

Do not put too much on a visual. A detailed table may not be readable in the back row. When making a visual, put yourself in the audience and ask yourself whether you could learn anything from it if you saw it only for 30 seconds or a minute. Short, concise statements of a few words on the visual, with the speaker providing a more detailed explanation, are sufficient to convey your points. Use colors effectively, but do not go overboard. Test all of your visual aids in the presentation room or in a room of similar size and shape to be sure that all information on your visuals is clearly readable.

The format and rules for presenting figures, tables (use sparingly if at all in oral presentation), equations, etc., are identical to those in the document *Written Design Reports.*

Colors in visuals can be a useful tool. However, colors should be used wisely and effectively. Typically, this means no more than four, as a general rule. Also, try to be consistent in the use of colors; if you use red for the fixed cost of the heat exchangers and blue for the fixed cost of distillation columns, then use the same colors for operating costs for the same equipment.

Presentation Mechanics

Always face the audience. If you have to look at the screen, take a quick glance and then turn back to the audience. If using overheads, you can look at the transparency on the projector rather than turning toward the screen. Be careful not to block the view of a portion of the audience. If someone else is changing your transparencies, stay back next to the screen. If you are changing your own transparencies, step back away from the projector after making the change.

Avoid the following nervous habits: chewing gum, playing with the pointer or something in your pocket, rocking from side to side, or giggling. Approach the oral report with confidence and a firm belief in your abilities and your work.

Never read text visuals word for word, line by line. Visuals should be brief. Your job as a speaker is to amplify the content of the visuals.

Voice

Speak clearly, enunciate carefully, avoid audible pauses, and project your voice. Speaking softly usually implies to the audience that you are unsure of yourself; probing questions will generally follow.

Be Calm

You are in control, not the audience. Beforehand, arrange the room in whatever pattern makes you feel most comfortable. Do you want to point with your left hand or your right? Do you want the shades open or the lights out? Then, do not make last-minute changes in your presentation. Immediately before your presentation, take a few deep breaths and yawn. (This is easier to do if you are not in the presentation room.) If you do not want to be interrupted with questions during the presentation, tell the audience so. And, if they still interrupt, politely tell them that you will be answering that question later. Assume that everything is going to go well.

Notes

To use or not to use? Do whatever will make you most comfortable and in control. If you read entirely from a script, no one will believe that you know what is going on. But no one can remember every detail without notes. When you practice your presentation, try it with and without hand-held notes, if you are not sure which is better. As a novice, you might find that hand-held notes bolster your confidence; however, with practice, you should wean yourself from using notes. Eventually, you will be able to use the content of the visual as your notes.

Audience Analysis ("Know Your Audience")

Just as with a written report, think about the different backgrounds and needs of your audience. Will they get the right message and make the right decisions?

Question and Answer

Admit it when you do not know the answer. Most people ask a question only because they do not know the answer, either. Try to be responsive, not evasive. And prepare for Q & A by imagining the questions that will be asked.

Postmortem

After the presentation, go with your colleagues to a less-tense room and get feedback immediately. Ask your colleagues what you could have done better. If they tell you that you were perfect, tell them that they are not being very helpful. Demand criticism! This is the best time to find out what you did right and what you did wrong. If you wait more than about an hour, the feedback will not be detailed enough to help you.

29.4 SOFTWARE AND AUTHOR RESPONSIBILITY

Word processing, spreadsheet, and graphics software can help an author produce a better final report, but each software package has limitations. It is the author's responsibility to understand these limitations and to overcome them. Some of these software problems are the results of programming errors, some arise from misunderstandings by the software developers of the rules of writing, and some represent differences between technical writing and other forms of written communication.

Above all, though, writers should save their files frequently and make backup copies.

29.4.1 Spell Checkers

Misspellings have always been unacceptable in formal written work. Readers generally have a lower opinion of the ideas expressed when the prose contains misspelled words. With spell checkers being so available, spelling errors have come even more to indicate sloppiness and lack of respect for the audience.

Clearly, one cannot submit a report that has not been subjected to a spell checker. However, no spell checker is perfect. More importantly, they can only check whether the "word" in question is *a* true word, not whether it is *the* word that the author intended. If one writes "to" when "too" is meant (or "preform" instead of "perform"), the spell checker will not correct it.

All spell checkers allow the author to add words to the dictionary. Many technical terms are not in the standard software dictionaries, so it is tempting to put in many words common to the author's subject. However, this is a risky business. If one puts a misspelled word in the user dictionary, nearly all of the author's reports will have that misspelling, without the author having a clue! Also, it is usually far more difficult to remove a user-supplied word from the dictionary than it is to add one.

Most spell checkers automatically suggest another word when they detect a misspelling. If one too quickly accepts the suggestion, rather strange prose can arise. In a technical report, we once somehow accepted the suggestion of "voices" for "VOCs" (volatile organic compounds)!

29.4.2 Thesaurus

In most writing courses, students are warned not to misuse a thesaurus. It is tempting to use a new word, one that sounds more sophisticated. Unfortunately, the probability that the new word can be substituted directly (without a modification of meaning) is nil. The thesaurus is designed to be used to *remind* one of a similar word. If the thesaurus suggests a word that you have no memory of, do not use it. Many satirical papers have been written about the blind use of a thesaurus.

29.4.3 Grammar Checkers

Grammar checkers continue to improve, but most are based on simple rules that apply imperfectly to technical communication. For example, the use of the passive voice is frowned upon in much nontechnical writing, but it can be the more appropriate voice in a technical report. The passive voice places emphasis on the object receiving the action rather than on the subject taking the action. Although the passive voice is often overused in technical writing, it does have its place.

Crude distinctions are often made by spell checkers. For example, some will flag each instance of "affect" and ask if the author meant "effect" (or vice versa). This can be tiresome, but one must be sure to understand the significant difference between these words.

Especially in long sentences, grammar checkers tend to become confused and flag correctly written passive constructions and subject/verb agreement. It is important not to accept the suggested changes too quickly.

Various readability indices are included in grammar checkers. These are crude measures of the ease with which a reader can read and understand a document. Most predate the computer grammar checkers. A document with a good readability index could be totally incomprehensible, and one with a poor index might be quite good. One must not read too much into these indices. However, they do focus on elements of good writing, such as short paragraphs, short sentences, short words, and straightforward grammatical constructions. Thus, one should watch the readability numbers for sudden shifts to longer words, sentences, and paragraphs. If the same information can be conveyed in a simpler format, it is likely to be more helpful to the reader.

29.4.4 Graphs

For much graphing software, the default graph type is not the common *x-y* plot, even though these are by far the most common in technical communication. If the independent variable (on the abscissa or horizontal axis) is numerical and continuous, this type of graph must be used. Bar charts and histograms are used only for nonnumerical or (sometimes) discrete variables. Unfortunately, there is a type of graph that looks vaguely like an *x-y* plot but is more like a bar graph. It is called a line chart. The line chart has evenly spaced tick marks on the abscissa, but the numerical values at the ticks are not even intervals! Such a graph is very misleading in technical work and must be avoided.

Most graphing software will automatically choose the scale for both axes. Unfortunately, this is usually not acceptable. For example, it is common practice to use even numbers when both odd and even are not shown and to use numbers ending in 5 or 0 in preference to others. These conventions make it much easier for the reader. Also, there are often constraints (such as 0–100%), and it is sometimes useful to extend axes far beyond the last data point. For example, in a series of graphs, one should use the same scale on each to allow comparisons. Typical graphing software will do almost none of the above automatically. The best strategy is to use user-specified scales on all graphs.

The lettering of the various parts of the graph should be clean and simple, and the more important parts should be in larger font size. This is rarely done automatically. The convention is to put the title of a figure (such as a graph) below the figure, although when the graph is presented by itself (as on a slide), the title may appear at the top. Titles should be properly capitalized: the initial letter of each word (except articles, prepositions, and conjunctions) should be capitalized. All other letters should be lowercase.

Strangely, some graphical software automatically inserts a legend on graphs. Unless there are multiple variables plotted, this should not be done. In any case, a direct label near the curve is more effective. One must avoid default legends such as "Series 1" that are distracting and offer no information.

Default headers and footers on graphs are seldom appropriate. One must override the default to number the pages consecutively in the report and to avoid double titles, multiple pages labeled "Page 1," and so on.

Most software connects plotted points with line segments (or splines) by default. This is often not appropriate. For example, if the points represent experimental data, only the points should be shown. Also, the joining of points obtained from process simulation on such a graph can obscure the maximum, minimum, and the shifts from one topology to another. More about these details is given in Chapter 14.

29.4.5 Tables

In some word processing and spreadsheet software, the default for numbers in table cells is centered. If this is the case, one must override the default and line up the numbers in a column by their decimal points. Only then can the readers easily compare the numbers or sum them. Also, the default format may be to include many significant digits. One must be careful to include only those digits that are, in fact, significant. Otherwise, either the readers will be misled about the precision of your answers, or they will discount your answers if they realize that you have exaggerated their precision.

When numbers have four or more digits to the left of the decimal point, they must have commas to help the reader to see quickly the thousands, millions, and so on, places. Only if the numbers are too cumbersome should powers-of-10 notation be used. When it is used, so-called engineering notation is preferred to scientific notation. In **engineering notation**, the power of 10 is always divisible by 3 (analogous to the commas mentioned above). In a column of numbers that all refer to the same kind of property, the format should be the same for each entry.

29.4.6 Colors and Exotic Features

Most software will allow multiple colors, fonts, and other features. Although their use may be tempting, too many changes can be distracting to the readers and cause sensory overload. On slides, use only as many colors as will clarify your results. Most members of your audience will not be able to distinguish between subtle shades in the time available; distinctions should be made with bold contrasts. However, one must not rely on color alone; almost any report will be copied in black-and-white! If your distinctions are not clear when the graphics are reproduced this way, there is a problem.

Reports in which dozens of fonts are used are distracting. Whenever the readers have any trouble focusing on the content, they tend to focus on the variations in font size or type. Thus, one should use a few font changes to focus attention, but the report should not appear to use every available font. Also, the more exotic the font, the less likely it is that the file will be compatible with other word processors.

A very serious problem is the improper use of "3-D" figures. If a graph is a plot of a dependent variable versus one independent variable, the graph is only a two-dimensional representation. Any attempt to make it "faux 3-D" will make it less readable and more confusing. Features such as giving a pie chart a constant thickness or the bars of a bar chart constant depth make the chart less useful in conveying data. Such gimmicks are viewed as such in technical reporting. The same can be said of "shadowing" of two-dimensional figures.

When a graph is truly three-dimensional (two independent variables and one dependent variable), one must be careful to use a perspective that allows the reader to determine easily the height (the dependent axis) at various points. The most useful such perspective is the "isometric" perspective, which involves rotating the straight-on coordinate system by 45° and then tilting it up in back by 30°. In this perspective, the distances perpendicular to the axes are not distorted.

29.4.7 Raw Output from Process Simulators

Process simulation software typically will produce a flowsheet, but this is probably not a true process flow diagram and should not be used as one in a report. There are two reasons for this. First, the simulator-produced flowsheet is unlikely to follow all the conventions of PFDs given in Chapter 1 regarding equipment symbols, line crosses, labels, and so on. Second, the process simulated is not the true process. One "unit" in the process simulator (such as a distillation column) may be several pieces of equipment (tower, condenser, condensate tank, etc.) that need to be shown on a PFD. It is common to simulate a single unit (such as a process-process heat exchanger) as two units to decouple the recycle calculations. Some units, such as a storage tank, require no calculations in the process simulator and thus are not shown on its flowsheet. However, the simulator flowsheet is essential in the appendix of the report if the simulator "report" is included. Care should be taken to use the same stream numbers in the simulation flowsheet as in the PFD whenever possible.

The report from a process simulator should be included in the appendix, but it serves neither as the main PFD nor as the main flow table. These reports are formatted for use by the user of the software, not by the reader of a report. Therefore, they should be considered as are the calculations in the appendix. They are referred to by the engineers who need to know the details, but they are not of interest to other readers of the report.

29.5 SUMMARY

Effective written and oral communication is crucial to the success of chemical engineering projects and to the success of chemical engineers. The keys to effective technical communication are performing an audience analysis, following the format of the organization, and obtaining and acting on feedback from colleagues.

WHAT YOU SHOULD HAVE LEARNED

- There is no single, correct format for a written report.
- If your company or academic department has a prescribed format, it should be followed.
- Written reports should be written with correct grammar, be correctly punctuated, and be appropriately organized; figures and tables should be neat and legible.
- Oral presentations should be appropriate for the audience, and an oral presentation on the same subject may be presented differently to different audiences.
- Visual aids are meant to enhance the presentation; they are not to be read, word for word, during the presentation.

REFERENCES

1. Leesley, M. E., and M. L. Williams, "All a Chemical Engineer Does Is Write," *Chemical Engineering Education* 12, no. 4 (1978): 188–192.
2. Munter, M., *Guide to Managerial Communication*, 9th ed. (Upper Saddle River, NJ: Prentice Hall, 2012).
3. *Effective Communication for Engineers* (New York: McGraw-Hill, 1974).
4. Ulman, J. N., and J. R. Gould, *Technical Reporting*, 3rd ed. (New York: Holt, Rinehart and Winston, 1972).

PROBLEMS

1. Obtain the written report guidelines used in your department for laboratory reports. Compare them to those in Section 29.2.8 and explain the differences.
2. Exchange a report you have written for one by a classmate. Spend three minutes skimming the report, and write down answers to the following three questions:
   a. Why was the report written?
   b. What is the author's key conclusion or recommendation?
   c. What would you do, based on the report?

   Then discuss your answers to these questions with each other.
3. Obtain the written report guidelines from a firm that employs engineers. Compare them with those in Section 29.2.8 and explain the differences.

4. Ask a chemical engineering student who has not yet taken design to read a report you have written and to point out the difficult passages. Rewrite the report so that it satisfies those concerns.
5. After giving an oral presentation, perform a postmortem analysis with a couple of members of the audience.
6. Write a short (one-paragraph) audience analysis for a design report in your design course.
7. Choose a graphing, drawing, or spreadsheet software package. Investigate the features of the package and make a list of those features that can lead to poor visual aids.
8. Run a grammar checker and spell checker on one of your reports. Accept every change suggested and then reread the report. What do you conclude?