Appendix (Online Only)

A Guide For Technical Writing

A report is the most common way to communicate and to archive engineering test results. Depending on the intended audience, reports usually take on one of three formats, with wording and purpose directed towards that audience: (1) Executive (or Extended) summary, (2) Laboratory (or Test) report, (3) Technical paper. All reports share common elements: Background - *Why* did you do the test, Approach - *How* did you do the test, Results - *What* did you find, and Conclusions - *So what* do we now know. These reports differ in purpose, and consequently, they differ significantly in focus, length and detail.

The executive summary is intended typically either for upper level management who will plan decisions around the input from the report or to communicate to an interested group the ~~principle~~ principal outcome of a study. The summary consists of short (usually under 500 words) elements stating the reasons for the tests conducted (*why*), the approach (*how*),the most important result (*what*), and the conclusions (*so what*). The document composition is subdivided into *Objectives*, *Results*, and *Conclusions* although these headings need not be used explicitly. A summary may include a key figure or a chart and key references, as needed. Because of its brevity and readership, the strategic use of words and clearly directed and meaningful conclusions are crucial.

A laboratory or test report is an internal report usually accessed by members of your engineering group. These reports communicate information in a way that educates the reader and archives useful information. The format stresses methods and results in detail. These reports should include the reasons for the tests, the pretest planning, the methods and test conditions used, with an emphasis on the discussion of the results, quality of results (uncertainty), and conclusions. The document can be subdivided into headings of *Objectives, Approach, Results and Discussion, Conclusion*. Related and prior works are clearly referenced. Data in the form of tables and graphs are cited and discussed within the report. Because of its overall length, a laboratory report may begin with an *Abstract* as a 200 words or less snapshot of the report contents. Because these reports document test methods and findings, laboratory reports may become legal evidence to justify device performance or test outcome should performance or function ever be challenged.

A technical paper is used to disseminate new engineering information to a broader technical audience outside of the immediate work group. Common forms can be found as a technical bulletin, conference paper or journal article. These are written at a level and style that is appropriate for the receiving audience. Accordingly, these reports should include and/or cite sufficient background information so that the reader can understand the purpose of and the history behind the tests, the hypothesis or question being tested, the manner in which the tests were analyzed, the discussion of the test result and their implications, and a conclusion. A technical paper must present enough information for the reader to understand the author's conclusions. Data should be presented only in

the form of well-prepared tables and graphs cited from within the paper. The paper ends with a concise conclusion. These papers often have length and figure limits, depending on the publisher, usually in the range of 4000 to 6000 words.

Each company, publisher, or professional group has its own exact format for these reports but as they all follow similar themes, we can provide guidelines below. Regardless of format or length, a report must communicate the purpose and the outcome of a test to the intended audience. Further information concerning technical reporting may be found in numerous guides for technical writing (1, 2).

A GUIDE FOR TECHNICAL WRITING

Competent engineers can communicate their ideas in both oral and written formats to both technical and non-technical audiences. This primer is intended as a brief guide to constructing a report intended for a technical audience. The organization of this section is itself representative of most technical reporting formats (3). The major headings, such as Abstract and Introduction, are typical, but are not meant to be exclusive.

Abstract

Effective technical communication abilities are important traits for an engineer in a technologically advancing society. A technical report provides a means to document and to disseminate relevant technical information, such as test or modeling results. The purpose of this article is both to provide specific procedures and ideas for generating sound technical reports and to serve as a format example for such a report. Guidelines for preparing each section and detailed ideas for presentation of results in plots and tables are provided. The reader can draw from this outline to prepare a technical report on a chosen subject.

Introduction

In a 2002 report, the U.S. National Academy of Engineering concluded that the majority of Americans "are not able to make well-considered decisions . . . about technology (4)." Our ability to communicate effectively with both technical and nontechnical segments of society is essential for addressing the myriads of technological problems and decisions facing our society. On a more personal level, career advancement in any profession is largely based on how well a person communicates among peers. The primary form of written communication used by practicing engineers and engineering managers, as well as researchers, is the technical report in one of its variations: the executive (or extended) summary, the laboratory report, or the technical paper. Technical codes and standards would fall into one of these categories, as well. Collectively speaking, these communications are directed toward a technically knowledgeable audience. However, with a shift in focus from methods to outcomes, these can be written to communicate technical findings to a broader audience. The purpose of this guide is to provide reasonable ideas and suggestions for producing clear and concise technical manuscripts.

The following steps may help you prepare an effective document:

1. Always clearly define the question, the question being the objective of the study to be described by the report!
2. Your report should flow from what you sought to show and why it is important, to how you tried to answer it, to what you found, and finally to what those findings mean. Start with a

detailed outline using this logic flow. Then expand your outline to at least the level where topics and some sentences have been formulated. The outline will help you avoid making a chronological or "stream of consciousness" presentation, which is not desirable. This will enable you to develop the rationale for your question and how you attempted to answer it in a logical manner.

3. Analyze your data, creating meaningful figures and tables. Then, organize your discussion on what this information shows. In terms of answering your question, which figures and tables are important and which are not? Use what is important. When deciding on just what to present, keep the particular audience for whom you are writing in mind.
4. Set your format or headings using the format or style guide for a specific publication, workplace template, or use this Guide. Organize around those headings.
5. Write a first draft in which you add meaningful sentences to your outline under each heading.
6. Read the draft, and then rewrite it for presentation clarity and accuracy. Your audience cannot read your mind, just your report – put what you want to say in writing. Remember that you are telling a technical story, so think clarity as from the reader's point of view. Proofread the manuscript. If possible, have a peer read the draft and ask for effective feedback on clarity and content.
7. Use a typography that is easy to read, such as 12-point Times or Arial font. Maintain margins of 1.25 inches (32 mm). Number all pages (exception: page one may be left unnumbered).

Approach

The supporting blocks for constructing an effective technical document are the written text, well-prepared figures, and clear tables, and an organized structure that communicates the story. Present the report from the standpoint of your current knowledge. You do not need to report on bad data, failed trials, blunders, and so on unless these are vital to your conclusions. Instead, take a fresh look at the results and organize the flow of your document to present the work in an effective way. In most technical documents, figures and tables provide the substance for the purpose, results, and conclusion of the study and so these should comprise a good bit of your discussion.

The following headings can be used as a guide for preparing each section of a technical document. *Just a note: these sections are not absolutes, just a guide.*

The Abstract—A Summary of the Entire Report

An Abstract is a complete, concise distillation of the full-length report. It contains a brief (one sentence) introduction to the subject, a statement of the problem and question studied, highlights of the results (quantitative, if possible), and the conclusion. It must stand alone without citing figures, tables, or references. It is written after the main body of the report is complete. The purpose of an Abstract is to be a concise summary. Abstracts are usually about 200 words.

Similar in organization but using more like 500 words as a common length, an Executive (or Extended) Summary does not need an abstract. It may include a critical figure, table, or chart, and key references. Whereas an Abstract summarizes a lengthy report, the Executive Summary serves as its own document.

The Introduction—Why Did You Do What You Did?

An Introduction provides the necessary background information, including appropriate literature review, develops for the reader a clear rationale for the work, and clearly states the objective of the report. This is where you develop and then state the hypothesis or question tested. The Introduction does not contain results, and generally would not contain equations. It could contain a figure or table as needed to develop the rationale.

Approach – What was done and how?

The Approach section contains the methodology used in the study. This might include separate sections describing descriptive analytical, experimental and/or numerical models, as appropriate.

Analysis—Is There A Model? An Analysis section develops a descriptive model used in the study. Sufficient detail (mathematical or otherwise) should be provided for the reader to clearly understand the physical assumptions associated with a theory or model. This will help explain what information was needed from any supporting experimental or numerical tests.

Experimental Program—What Did You Measure and How? The Experimental Program section is intended to describe how the experimental model was developed to support the analysis and so test the hypothesis, and to detail how the results were obtained. Provide an overview of the approach, test facilities, verification studies, and range of measurements in just sufficient detail that the reader understands what was done and how. Do not give instructions, this section should not read as a recipe. The relationship of the analysis to the experiment should be made clear. Often, the experiment provides the values used to complete or to test the analysis.

Numerical Model—What Did You Simulate and How? If a numerical simulation was performed, it should be described under a separate heading using the same guidelines as presented for the Experimental Program.

Results and Discussion—So What Did You Find?

In Results and Discussion, you present and discuss your test results and tie them back to your original hypothesis. For technical papers or laboratory reports, this section will usually be the longest section of the document. Describe the operation conditions and range of tests done and then present each finding. When presenting your results remember that even though you are usually writing to an experienced technical audience, what may be clear to you may not be obvious to the reader. Guide the reader towards your interpretation. Tell the story.

This section is where you transform the raw data in your notes into meaningful results within the report. Often the most important vehicles for the clear presentation of results are figures and tables. Each figure or table should be numbered, labeled with a caption, and cited by number within the text. *As a good rule, spend at least one paragraph discussing each figure or table.* Tell the reader exactly what is presented in the figure or table and then discuss the behavior of the data and its importance. For any experimental or numerical study, you should include a synopsis of your uncertainty analysis culminating in a statement about the quality of the results presented.

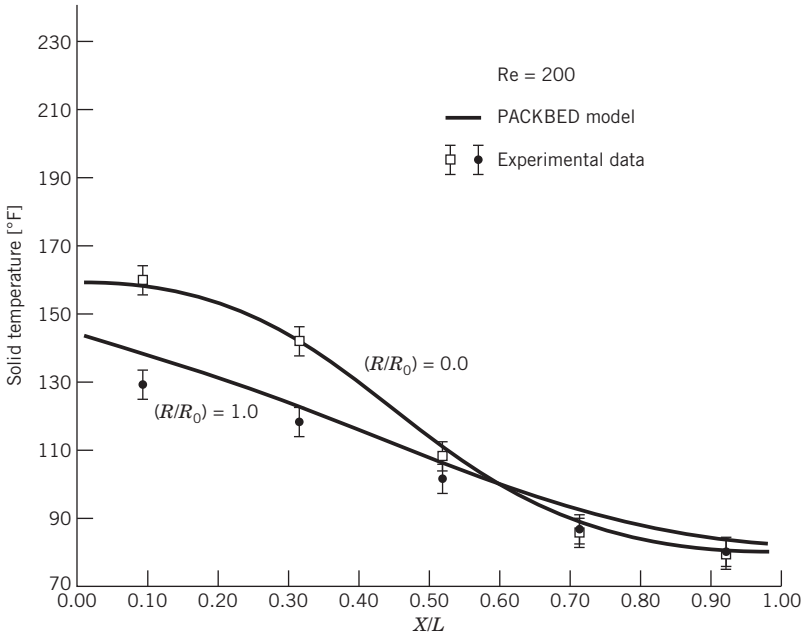

Figure 1 Comparison of experimentally measured and computed results for axial temperature distributions in a thermal energy storage bed.

Figure 1 shows an example of an appropriately prepared plot. Note that this plot has a figure number and a descriptive caption, and clearly labeled axes. As an example of what to write: your report might start with, "*the measured temperature as a function of position within the heated, packed particle bed is shown in* Figure 1. *Here radial position, R, within the bed is normalized by the bed radius,* R_0*, and axial position, x, within the bed is normalized by the overall bed height, L. Two curves are shown, one taken along the centerline* $(R/R_0 = 0.0)$ *and the other along the bed wall* $(R/R_0 = 1.0)$*. Also shown are the corresponding model predictions. The measured bed temperature is essentially uniform between the centerline and the wall for* $0.5 < X/L < 1$ *but shows spatial gradients as large as* $20^{\circ}F$ *for* $X/L < 0.5$*. Error bars represent the 95% confidence intervals.*" Then the extended discussion of this figure might focus on the differences in the curves, why they are different, how they relate to a model or prediction, and assess whether their shape and magnitudes make sense. Be sure to cite any corresponding equations used.

The visual impact of a plot conveys considerable information about the relationship between the plotted dependent and independent variables. Suggestions for creating effective plots:

1. The independent parameter is always plotted on the *x* axis; the dependent parameter is always plotted on the *y* axis.
2. Try to use at least four tics or increments for each axis. Multiples of 1, 2, or 5 are good increments because they make it easy to interpolate. Watch out for automatic scaling features from software: it is hard to justify strange increments such as 0, 7, 14.

3. In drawing smooth curves through experimental data points, try to follow these rules:
   a. Show the data points as symbols, such as open or filled squares, circles, or triangles.
   b. Do not extend a curve beyond the ends of the data points. If you need to extrapolate, then use a dashed line outside the known range. Indicate the curve-fit equation used.
   c. If you are certain that $y = 0$ when $x = 0$, put the curve through the origin. But if you are uncertain, don't use the origin; stop the line at the lowest point (see 3b).
4. Use a minimum variety of symbols for your data. Always include a symbol legend. Consistently use the same symbols for the same variables between graphs. Pick a symbol font size that will be legible.
5. To compare experimentally determined data with model predictions, show the experimental points as symbols and the model as a smooth curve. Similarly, show numerical predictions as a smooth curve. Clear labeling is essential for this kind of plot.
6. The figure should contain enough information to stand alone, especially if there's a chance it will later be used by itself (e.g., as a slide).
7. Use axes font sizes that will be readable should the graph be altered in size, such as to be used in a slide presentation or transferred to another report.
8. Adjust the graph scales so that the curves are not bunched near the top, bottom, or one of the sides.
9. Uncertainty limits should be indicated for a number of measured points on a given plot using interval bands about the mean value, as shown in Figure 1

Table 1 is an example of results presented in a tabular form. The table has a number and a descriptive caption. As an example of how to describe a table, your report could start with, "Table 1 *lists the measured thermistor voltage output as a function of the applied velocity.*" The extended discussion of this table might focus on its range, curve fit, how it relates to a model or prediction and how it is used.

Conclusions—What Do I Now Know and So What?

The Conclusions section is where you should concisely restate your answer to the two questions: "What do I know now?" and "Why is that important?" Your answer must support or refute your

Table 1 Characteristics of a Thermistor Anemometer in a Uniform Velocity Flow Field

Velocity [m/s]	[V]
0.467	3.137
0.950	3.240
2.13	3.617
3.20	3.811
3.33	3.876
4.25	3.985
5.00	4.141
6.67	4.299
8.33	4.484
10.0	4.635
12.0	4.780

original hypothesis and provide a useful closure to the report. The Conclusion is a short summary that restates why the work was done and how it was done and focuses on why these results are significant. This is not the place to offer new facts or discussion. A conclusion will normally have a quantified outcome. An example might be: "*The temperature measuring system was calibrated against a laboratory standard RTD. The system was found to indicate the correct temperature over the range of 0 to 150°C with no more than ± 0.5 °C uncertainty at 95% confidence. This is acceptable for the intended use in our product.*" It would not be appropriate to conclude simply, "The temperature measuring system was tested and worked well enough."

Conclusions should be clear and concise statements of the important findings of a particular study; most conclusions require some quantitative statement with context to be useful.

Appendices

Appendices are places to put non-critical, supplemental or supporting information, such as raw data, lengthy derivations, or sample programs.

Appendices are independent from the report and as such, they are often misused by a new engineer. Uncertain as to whether or not some information should be in an Appendix? Ask yourself: If I place this material in the Appendix and the reader did not read the Appendix, would the main body of the report still be sufficient? It should be!

References

The references cited within a report should be detailed in a formal list at the end of the report. Use references that provide credit for prior work but also to provide more information for the reader. For example, did the test program follow an established engineering standard? Then provide a citation so the reader can go to this standard for reading. If you used an internet webpage or web document, cite the URL and the date used. References for this document provide an acceptable general format for citations.

Some Writing Tips

1. Communicate! You are telling a story, albeit a highly technical one. Have someone else read it, and then rewrite it as needed! Proofread the final manuscript.
2. Do not overdo significant figures. See the discussion in Chapter 1.

On Writing Style

Engineers often write reports in the third person in deference to impartiality and to focus attention on the subject matter at hand. The idea is to disassociate the writer from the action and make the equipment/model/test the "doer of the action (5)." This is a notable goal but one that takes time and practice to do effectively. But achieving this goal does not require extensive use of the passive voice, despite traditional beliefs to the contrary. Do use the active voice where possible to liven up your report and try to use as few of words as possible to communicate an idea.

Conclusions

Technical authors must be cognizant of coupling the intended audience with the test goals when presenting the results of their writing. This paper has outlined the essential features germane to

technical report writing and it serves as an example of both style and format. We describe several report types and detail the purpose and content for each section of a report. We also pass along some useful advice drawn from our experience in helping young engineers learn to write technically and offer specific examples for presenting results in figures and tables. We conclude that an effective, professional product can be produced only through careful revision of manuscript, by incorporating effective figures and tables, and by targeting the intended audience.

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