University of Washington

Materials Science & Engineering Department

LAB REPORT FORMATS

General Considerations:

A report based on a laboratory experiment serves several purposes. First it is a logical method of consolidating and presenting information for conveying to the instructor your understanding of the subject material. Second it makes available in condensed, accessible form a ready reference about that subject in the form of text-specific citations which provide background information, as well as a research resource for further, future work. Finally, it provides hands-on experience in preparing the many technical reports and, perhaps, articles for publications that you will be expected to write throughout your professional career.

All reports should be prepared on computer using a word processing program; dot-matrix print quality is acceptable. No reports will be accepted in manuscript (i.e., handwritten) form. Departmental computers for undergraduate use are located in Mueller Hall, room 178; a laser printer is available in Mueller 183. All reports should be typed, double-spaced on standard 8 1/2" x ll" paper; the style of presentation, correct spelling and appropriate usage are considered an important part of a well written document. All data graphs should be computer generated although formulas and calculations may be written in ink.

General report writing guidelines:

1. Organize your report according to the sequential model presented in the Report Style Manual handout (see page 5).
2. Plan and outline the largest portion of your report *before* starting to type at the computer, in order to both save time as you compose your thoughts and to better organize those thoughts as you write.
3. Convey your experimental findings and subsequent understanding of the subject in a complete but concise manner. A brief but well-written report will be much more successful and well-received than a lengthy, poorly-considered one. Remember *quality, not quantity.*
4. Develop the *Results* and *Discussion* section(s) as the fullest portion of your report, making connections to the introductory opening section as appropriate. Strive for continuity between the various sections of the report; always specifically address the overall lab objectives as you introduce and organize your material.
5. Write the Abstract last.
6. Proofread the final typed copy, a practice which reflects not just your careful preparation of the report, but a final, careful rereading of its content as well. Make any final, local corrections neatly in ink.
7. *Do not use report Covers.* Instead, simply staple your lab report in the upper left hand corner. Include a cover page stating the name of the class, the assignment, your name, the instructor's name, and the date.

Long Report Format:

The long report form should be used for every lab report other than those designated *short form report*. Long reports should consist of these major sections:

1. Abstract
2. Introduction
3. Background information
4. Experimental procedure
5. Experimental results
6. Discussion (including error analysis)
7. Summary and conclusions
8. Cited references
9. Appendix

Each of these sections should be written according to the descriptions which follow.

Abstract

The abstract is a summary of your report from which the reader should be able to tell (1) what problem your report addresses, and (2) what significant results were obtained. When composing the abstract you may find it useful to organize according to a sub-outline, similar to the larger outline of the lab report itself. First, introduce the problem and describe why it is worth studying. Next, identify a hypothesis regarding the work you have performed and the goals of the experiment. Continue the abstract by briefly discussing the experimental approach; and conclude with a brief summary of the experimental results, including any significant conclusions. For example:

> One of the primary goals of ceramic processing is to produce a dense specimen at the lowest possible sintering temperature. In order to identify the best processing route, a series of -$A120_3$ samples was prepared by colloidal. filtration, dry pressing, and extrusion. The specimens, were heat treated in air and held at various temperatures for one hour. After the heat treatment state, the density of each sample was measured and compared to determine the temperature at which densification was completed. Results demonstrated that samples prepared by colloidal filtration densified at 1500^0C, while the samples prepared by extrusion and dry pressing both required 1600^0C.

In reading this sample abstract, you immediately get an idea of the experiment, the procedure, and the results. For additional and various sample abstract formats, refer to one of the many publications in the Materials Science field, such as the *Journal of the American Ceramic Society, Acta Metallurgica,* and *Materials Research Society Bulletin*. Also see other sources of abstracts, such as *Ceramic Abstracts* and *Chemical Abstracts.*

Introduction

Begin the introduction with a brief statement regarding authorization, purpose, and scope of the work. Include a review of the available literature which gives sufficient, pertinent background for the experimental work and discussion.

Procedure

This section should be a description of the actual procedure followed in the course of the experimental work; include a description of the equipment and materials used, as well. If the procedure for the experiment is, say a standard test adopted by ASTM (American Society of Testing and Materials) or a similar regulating organization, it is satisfactory simply to indicate that this is the case. Any deviations from standard procedure, however, should be noted in sufficient explanatory detail.

Results

This is one section of the report which is often misrepresented and misunderstood. Results should always be clearly set apart from the discussion of the results. Since many students have difficulty distinguishing between *results* and *discussion*, the following explicit definitions of these terms may be helpful.

Results are the direct product of your investigation. Often they are the values derived from measurements and raw data, etc., in an experiment, although they may, however, include other observations as well. Note that the raw data themselves are not results. The results are, in fact, usually not presented in the form in which they are taken down during the course of the study; instead, they are reduced to a more efficient method of presentation, including tables, graphs, curves, etc. (more information on these methods will follow). The results can also include statements concerning important aspects or interesting features of the data. The presentation of results should be straightforward and as concise as possible, while remaining complete.

In the short report format, the *Results* and *Discussion of Results* sections are combined into a single section entitled *Results and Discussion.* Although this combined form represents a streamlined version of the two fully developed sections, it is nevertheless important that the presentation of the results and the discussion of those results be clearly distinguishable lines of thought. It is critical that the writer be able to make the distinction between these two both in writing as well as in his/her own mind.

Discussion

Discussion of the results is much more difficult to describe and to do. Usually, discussion can be divided into three general areas:

1. Validation of results,
2. Development of arguments which you use to interpret your results and combine them with others' results to lead to significant conclusions, and
3. Comparison of these conclusions with existing knowledge (e.g. that which was presented in the introduction section).

Validation of results takes a number of forms. Remember that you are attempting to convince the reader that your results are credible, so you should try to dispel any possible doubts by:

1. Discussing the accuracy and precision of your observations. How repeatable are they? Have you used statistical methods to reduce the effect of random error? What is the readability of your instruments, and how do the errors combine in calculations? Note: This method explains the magnitude of the random error of the data.

2. Comparing your results with the results of others on the same or similar systems. For instance, if you measured the electrical conductivity of $A1_20_3$ you would expect it to be nearer that of MgO than of a metal (this is an extreme example, but one which should make clear the principle). **Note:** This technique assumes that no large systematic errors have biased your results.

Summary and Conclusions

This section of the report should be relatively short, presenting the conclusions reached in the discussion in strongly-stated, concise sentences with as few qualifications as possible. Note that negative conclusions may often be just as valid as positive ones.

Cited References

This section will include all reference material used by the writer in conjunction with the particular experiment. Use the citation form recommended by the *American Ceramic Society* or the *American Society of Metals.* Entries should be numbered according to their appearance in the text of the report, where they are cited by a number in parentheses or with a superscript.

If questions are included in the lab hand-outs for a particular experiment, responses may be presented in the "Discussion of Results" section or in an appendix, as appropriate.

Short Report Format: *(2-5* double-spaced pages plus appendix, if appropriate)

Purpose: A short form laboratory report provides a format for reporting data to supervisors in a concise yet informative manner. Often, professional reports are unnecessarily lengthy and "wordy," resulting in lost time for both the preparer (writer) and recipient (reader). Readers of short form lab reports are most interested in conclusions, rather than background information, and in the main results from which those conclusions are derived. At the same time, however, sufficient details must be included should the supervisor choose to check or expand upon the presented work.

Format: A short form report is written with the assumption that your supervisor is well acquainted with both the theory and the standard procedures which underlie the experimental work. Therefore, only brief references to these items should be included. The report proper should consist of:

Abstract

Introduction - including the purpose and scope of the research; a statement of the problem; standard experimental procedures used, as well as any deviations from them (any substantial deviations from standard procedures should be included in an additional section labeled "Procedure").

Results and Discussion — including error analysis

Summary and Conclusions

References

Appendix — if appropriate

REPORT STYLE MANUAL

I. Format

Acceptable general formats for lab report writing are those for the short form report and the long form report (described in the preceding pages.)

II. Introduction

Every report should contain an initial, introductory statement which speaks to the following three points: authorization, purpose, and scope. In the case of a short form report, these may be covered in one or a few sentences. For a long form report, approximately a paragraph for each point is more common, although they may occasionally fill up several pages. The introduction to a short report also describes the experimental method and, perhaps, a short background discussion. In a formal report, these are expanded into discrete sections of their own and are often labeled Background Information", "Theory" or "Literature Review", and "Experimental Methods".

III. Results and Discussion

This is one section of the report which is often misrepresented. Results should always be clearly set apart from discussion. Since many students often have difficulty distinguishing between *results* and *discussion*, the following explicit definition of these terms may be helpful.

Results are the direct product of your investigation. Often they are the values derived from measurements and raw data, etc. in an experiment but they may also include other types of observation as well. The results are, in fact, usually not presented in the form in which they were taken down during the course of the study; instead, they are reduced to a more efficient method of presentation, including tables, graphs, curves, etc. (more information on these methods will follow). The results can also include statements concerning important aspects or interesting features of the data. The presentation of resu1ts should be straightforward and as concise as possible; while remaining complete.

Discussion of the results is much more difficult to describe and to do. Usually discussion can be divided into three general areas: (I) validation of results, and (2) development of arguments which you use to interpret your results and combine them with others' results to lead to significant conclusions, and (3) comparison of these conclusions with existing knowledge (presented in the *Introduction* section).

Validation of results takes a number of forms. Remember that you are attempting to convince the reader that your results are credible, so you should try to dispel any possible doubts by:

1. Discussing the accuracy and precision of your observations. How repeatable are they? Have you used statistical methods to reduce the effect of random error? What is the readability of your instruments, and how do the errors combine in calculations? Note: This method explains the magnitude of the random error of the data.

2. Comparing your results with the results of others on the same or similar systems. For instance, if you measured the electrical conductivity of A1203 you would expect it to be nearer that of MgO than of a metal (this is an extreme example, but one which should make clear the principle). **Note:** This technique assumes that no large systematic errors have biased your results.

The second part of the discussion will attempt to take your results, combine them with others' results (i.e., from the literature, rather than from other lab groups), and draw some conclusions. This is the most difficult, and most creative, part of any technical paper, it is also the most valuable. There are libraries full of misinterpreted or poorly interpreted results which, if properly analyzed, could save millions of dollars in further research. Unfortunately, because it is so difficult, this part of the process is usually shirked to a lesser or greater extent.

The technique for comparing your results is difficult to describe. You should take advantage of all you know and of all you can find which relates to your work. At that point, the creation of new ideas - synthesis, reasoning, or whatever you want to call it - comes into play. This step is easier to some than to others, but all researchers can and do make progress in this step, primarily from repeated practice.

One frequent error which is made in this section concerns the drawing of conclusions from a set of results which does not include your own. To be included in this kind of report the arguments you make in this section must be based, at least in part, on your results. If you should see some wonderful idea coming from the combination of the work of others which they have not seen, that becomes the subject of a different paper.

Summary and Conclusions

The summary of your report should be concise and not more than one paragraph. It should contain a sentence regarding the purpose of the experiment and summarize your experimental methods and results. Brevity is, once again, important.

A "conclusions" section is not composed simply of a conclusion, but is comprised of the most important points which you have established throughout your work. They should correspond to what you initially stated in the introduction that you were going to do. Because they are the end result of the discussion and results, they should be supported in that section. Conclusions should be stated in short, clear, declarative sentences so that there is no ambiguity about their meaning. Often they are numbered, but this is not required.

In the short form report the conclusions can and often do actually precede the results and discussion (but not in our case). This does not mean, however, that you write them first. They are placed after the introduction for the readers' instructional benefit, not because they are written in that order. Please be reminded that, as explained above, conclusions not based on your work do not belong in a report of this type.

Appendices

An appendix is used for materials which is of secondary importance in the development of your work. One test of whether material should be included in the body of the report or in an appendix is whether the reader can follow the text of your discussion without reference to the appendix. Information necessary to the flow of discussion does not belong in an appendix. In lab reports, for instance, the raw data is appended if, as is usually the case, the data has been reduced to some other form and included in the body. Curves, tables, and sketches which are referred to directly in the text should follow the page on which they are first mentioned. If not necessary to the presentation of data or discussion, but only to the background discussion, they should be appended.

Calculations are usually best placed in the appendix, unless the calculation is a particularly unique one. Simple plug-in calculations should be shown by one example in the appendix.

In most cases, all of the data and values necessary to establish the final results should be included somewhere within the report so that the reader, if he/she finds it necessary, can check calculations. Often some of these are appended, since they are of secondary importance.

Curves, Graphs, Sketches, and Tables

The usual convention in technical writing is that tables are numbered in Roman numerals, and figures are numbered in Arabic numerals. All curves, graphs, and sketches should be given a *Figure Number* and referenced by that number within the text; tables should be similarly numbered and referenced. Each figure and table should have its own caption (or title) so that it stands alone, i.e., the reader doesn't have to go to the text to find out what the figure or table represents.

If graphs and curves are used to illustrate general trends, they can be plotted with come grids or even without grid lines. If, however, the curves will be used to extract values, they should be plotted with fine enough grids to make the extraction of data convenient and of sufficient precision. Figure 1 is an example of a graph with pertinent features of the presentation noted. The initials and date recorded in the lower right corner are a very convenient practice if the figure is pulled out of the report for use elsewhere, say in a summary report (this complete labeling of graphs and figures is generally a good practice). All graphs for the lab report should be prepared on computer using one of the several software packages available.

One common error in line graphs is in the choice of axes upon which to assign variables. The independent variable, according to convention, goes on the horizontal axis (abscissa); the dependent, on the vertical axis (ordinate). Frequently in our work, we use time or temperature as an independent variable, i.e., they are the variables we control. It is, however, not always that easy to decide how to assign the axes properly.

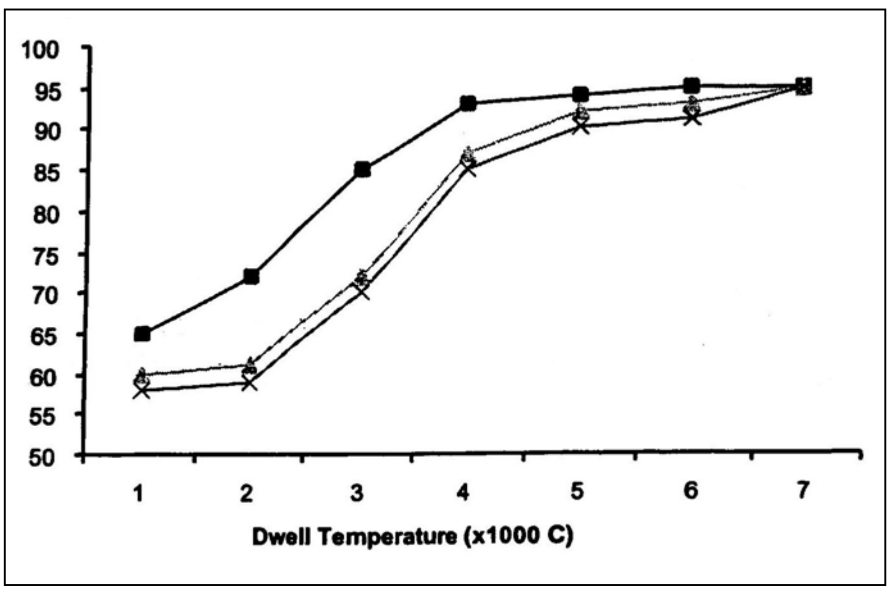

Figure 1. The densification behavior of -A1203 compacts prepared using three different processing techniques: colloidal filtration, extrusion, and dry pressing. Samples were heat treated at 10^0C/min to the dwell temperature, held for 30 minutes, then allowed to cool by shutting off the power to the furnace. Specimen density was obtained using the ASTM C20 standard test.

Abbreviations, Punctuation, and Spelling

As stated previously, correct spelling and appropriate usage are essential to the acceptable presentation of your lab report. Any good English language style manual and, most importantly, a good college level dictionary will prove helpful in this area. A good (although somewhat outdated) example is *Elements of Style* by Strunk and White, published by MacMillan. In addition, a technical writing handbook would also suffice. The style sheet published by the American Ceramic Society provides guidance in the use of technical and materials terminology.

References

Other researchers' work, to which you may refer in your discussion and/or literature review, are most easily incorporated by including a numbered list of references at the end of the body of the report (preceding the appendices). The citation number may be either a superscript, e.g. "Rice, et al[2]"; or the number should appear in parenthesis and follow the citation in the text: "...following the work of Rice, et al (2)". The form of the citation in the reference list should be that which is used in the *Journal of the American Ceramic* Society or the *Materials Research Society Bulletin.* The reference list should be presented in the same order as references are cited in the text.