Template for Writing Up Experimental Work

What will distinguish your work, both here in this lab, and later when you are working, is your skill in creating a write up that extracts the maximum information from the experiments and presents it in a format that is aesthetically pleasing and easily understood by the report’s audience.

This translates into giving the audience what they expect in terms of the report format and the general content of each section. Here is my expectation for this assignment which is approximately what most supervisors will expect from their direct reports who are reporting experimental outcomes:

**TITLE PAGE**
Title + authors + contact information + date + executive summary or abstract on first page

* A good title is short, conveying the most important issue addressed.

* Executive summary is about three sentences; abstracts are a little longer but less than 7 sentences in one paragraph.

* There are no pictures or artwork on the title page. There is no page number on the first page, even though it is page 1.

**INTRODUCTION**

Almost every document starts with a section called ‘introduction’ so it is highly expected. Give them what they expect.

* The purpose of this section is to provide the reason why the work was done and show how the work will contribute to and extend an existing body of knowledge.

If you had done this to learn more about some process in a corporate world environment, then you would indicate that here but in the present case you are writing this report in your role as students learning about the responses of steels to heat treatment. So, take a direct approach and report that this experimental work is to give you first-hand experience in the heat treatment of steel in support of the objectives of understanding the role of phase transformations in causing the ability of engineers to control the properties of steel by modifying its microstructure. This section should be about three paragraphs and generally should have the tone of motherhood and apple pie….that is, be such that the reader will of course agree with what you are saying. This
sets their mental attitude to what is coming. The goal of writing a document is to lead your reader through a series of thought processes in order to inform and or influence. This starts by getting them to be comfortable and accepting of what you are saying.

BACKGROUND

This is the body of work one should already know in order to appreciate the findings of the experiments about to be performed. This means you have to write a description of how heat treatment can be used to control the microstructure of steel and achieve different purposes. This is sort of a “term paper” on heat treatment of low carbon steel. Be sure to use several references so that you have a thorough understanding of the material, and, as a rule of personal practice, for the purposes of academic honesty, never cut and paste anything or look over your references to help with the wording. Write from your own mind. It is okay to use quotes if you feel something was so well worded that it deserves such recognition. If you quote text, use reduced margins or some other means of setting off the quoted text and include a numbered citation reference. If you reproduce a figure by cut and paste, at the end of the caption state the following parenthetical reference: (reproduced from reference xx, a publically available resource). If you need to reproduce a figure from a copyrighted work, this is NOT ALLOWED by cut and paste. You are allowed to redraw the figure in a way that looks like the original but is clearly a redraw. Add your own detail, labels, leave some parts out, etc. If you do this, then close the caption with the following reference: (figure adapted from reference xx). Note that this does not allow for the possibility of copyrighted photos since you have no way to redraw them. Some folks have been known to invert photos, crop them, etc. but this is not in the spirit of redrawing. Redrawing is creating the artwork from your knowledge of the concept and referencing the source of your knowledge. It is the artwork equivalent of referencing a source.

This section can be several pages or as short at a couple paragraphs. In the short version, you will end up referring the reader to sources that provide the background and this often comes across as shirking your responsibility. In my opinion, it is better to provide the background for the interested reader rather than sending them somewhere else. This way you are sure of their viewpoint and knowledge of the subject for what follows.

OBJECTIVE

This is the specific outcome desired from the work that is being reported. You can introduce short term and long term objectives if you desire. It is okay to say “The objective of this experimental work is to……” You can also discuss the experimental plan here showing how the experiments that are to be conducted can be used to accomplish the objective. This is a very brief section, two paragraphs at most.

EXPERIMENTAL PROCEDURE
This is a prose description of what was done in the experiments at a level of detail sufficient for others skilled in the art of conducting such experiments to carry them out. That is, this section provides the detail needed to reproduce the experiments. It is not a bulletized list. It includes detail of sample preparation and sample source, experimental set up, and data acquisition methods. It should show a figure of samples where this is not obvious from the description. For example, a sketch of the wiring diagrams, beakers, etc for the hydrogen charging set ups would be included here, perhaps as two figures for the two different set ups. It includes specific concentrations and sources of chemicals, how they were mixed, the type of holders used for the samples, descriptions of any special apparatus. If standard procedures were used, you can say that also such as: “Force vs displacement results were recorded using standard software provided by Instron Corporation as part of the screw driven mechanical testing system. Data files were labeled with sample number and transferred to a flash drive at the end of the lab session to enable subsequent analysis.”

**EXPERIMENTAL RESULTS**

The facts determined by the experiment are presented in this section. Usually these are in the form of graphs of experimental data. You should not simply present the facts but rather talk about them and compare them with other facts known to the reviewer. Walk the reader through the data so that they observed the important aspects. Make comments on reproducibility, error bars, You should make an effort to provide context for the results so that the reader can appreciated what has been measured and if the results are reasonable in light of other knowledge. For example, “the slope of the stress strain curve is 29.5 x 10^6 psi, comparable with the known value of 30 x 10^6 psi (reference) for hypoeutectoid steels.”

If tabular data sheets are included in the report, they are usually placed in an Appendix at the end but such tabular data is not often included unless there is a special reason. Small tables that sumarize findings are in the results. If you make many measurements, you may show example test plots and then use a table or another graph to summarize results. Both tables and graphs have captions. Here is an example figure with caption. I will also include some text to show how to reference the figure. The caption describes what is in the figure, then adds an explanatory sentence. This form works very well for people who “just look at the pictures” as it leads them to explore the text and reminds them of what you said in the text. It is also a recipe to get the caption written quickly. You can write the captions before you write the text so I often populate the document with the figures and their captions first as a means of organizing the report.
Fig. 3: Open circuit potential of low carbon steel alloy AISI 1010 as a function of time in hydrochloric acid (pH = 1.82). After the steady state was achieved, the magnetic stirrer was switched on to show both the transient and the shift in steady state. Note the increased noise in the signal.

Here is some sample text that goes with the above figure:

To better understand the electrochemical behavior of steel in acid solutions, the free corrosion potential of AISI 1010 samples was measured as a function of time as shown in Fig. 4. Figure 4 also documents the effects of sudden changes in liquid flow near the steel surface. As shown earlier in Fig. 2, the magnetic stirrer was positioned to induce a flow in the beaker that was nominally tangential to the broad face of the steel coupon, supported 0.5 cm from the perimeter of the beaker. (note the abbreviation and capitalization of Fig. except when it is at the beginning of a sentence where it is written out. This is standard formatting for referring to figures.

More notes on Style

Also, it is important to know that any equations or math symbols, Greek letters or variable names are in italics. For best results, use TIMES NEW ROMAN 12 point for the body text as I am doing here since it has the serifs that make it easy to read. Avoid ARIAL. (ARIAL) for the same reason. The stress, $\sigma$, and the crack length, $c$, are examples to show you the italics that you need to use. Also, italicize Latin phrases such as *i.e.* and *in situ*, among others. These days, *etc.* is so common that it is often not italicized but it is not wrong if you do. Lastly, use standard margins, single space, double space between paragraphs (blank line before major headings) with left justification and non-justified right margin to avoid the weird looking spacings that right justification sometimes produces. It irritates your readers. It is also customary to double space after the period at the end of a sentence because it enforces the pause
DISCUSSION

This section is for explaining how you think about the results, how they can be interpreted, what they imply, and to apply analysis methods to extract information from them. In short, it is the nonfactual results that you can obtain from evaluation of your experimental work.

For example, while the micrographs of your steel samples will be in the results section, the discussion can have a subsection entitled “Quantitative Analysis of Phase Content”. See how just using that title shows you know how to think about it. Here you briefly describe the point counting method and show data tables of the results of point counting to determine the volume fractions of the phases from the measured area fractions. Discuss the accuracy using square root N method to estimate the uncertainty of the value you obtain. 

http://stsdas.stsci.edu/cgi-bin/gethelp.cgi?explain_errors

Once you obtain the volume fraction of pearlite, compute the mass fractions using the density of the ferrite, carbide phases, and pearlite regions. This shows that you can use optical microscope analysis to determine the carbon content of a steel, particularly useful in troubleshooting issues.

You could introduce other sections where you examine your cooling rates by plotting them on either an isothermal TTT curve or a continuous cooling curve appropriate for the particular alloy. You can use the measured time for cooling with a recognition that the cooling rate should be proportional to delta T (your heat transfer background with a little excel to make a plot of the expected cooling rates and then transfer them to the log coordinate time of the TTT curve. There are many ways to lay this out but it essentially lets you explain why you got the microstructures that you observe and what they mean, including the hardness data.

Now, you also realize that you can use the hardness data to estimate the tensile strength of steels. We know that the hardness is effectively measuring the average properties of the stress strain curve so if the curve is similarly shaped, then the magnitude will let us estimate the UTS. So, in the discussion, it is worth going through this process to estimate the UTS of the three microstructures.

The discussion is where you also try to make sense out of any other observations such as the flaking of the surface. If you think about measuring hardness at different depths, this relates to Jominy End Quench methods so you need to discuss how this variation in hardness with depth occurs. You might also think about how much carbon might have been lost during the austenizing using your knowledge of diffusion. By going over all the little details, you will be
surprised at how your general knowledge of materials science makes it easier to understand why these experiments turned out the way they did. If you discover logic regarding why to cut the sample to examine the interior microstructure, mention this in the results section too. Did you look at the microstructure near the free surface? How could you do this? (This could be a future work subheading in the discussion)

CONCLUSIONS or SUMMARY

Here you pull out the main findings of the experiment. Learn the culture of your audience. Some will despise bulletized lists and others will prefer them. If you do not know, avoid the bullets by simply writing prose. If you need to revise, it is easy to create bullets from prose than vice versa.

Often, the results (the what you did) can be restated as a conclusion. Important points of the discussion, such as the estimate of the carbon content from quantitative microscopy should be here. The range of UTS values obtainable by heat treating this particular composition of steel also qualifies.

The conclusion should be consistent with the abstract or executive summary, of course.

REFERENCES

These are the numbered references that have been identified as sources for statements made in the body of the text.

BIBLIOGRAPHY

These are the sources that you used in preparing the report. Certainly your text book should be here. As styles evolve, websites will be here but some employers or professors may not accept them yet. Some universities such as ours https://urresearch.rochester.edu/home.action are creating archival websites that will have permanent links. For the purpose of reports written and submitted for this class, please include all the sources you used, including websites of any type. For other classes, check with the professor’s preference regarding the appropriateness of citing internet sources. You might add a caveat that while these links may not work properly in the future, they were active at the time of writing and similar sites can be found using search engines.