This guide will help you write your technical reports in the format required for EM 3XX. The first part tells you what’s included in each section of a report, the second part tells you how to format your report, and the third part gives you an example of a good technical report.

Every report you write should be addressed to an average engineer – not to your instructor! Assume the reader doesn’t have any detailed knowledge of your subject.
Part 1 – What Belongs in Each Section of a Good Report

Abstract

This section gives the reader an overview of your entire report. It includes a brief summary of the problem and the key elements of the solution. It should be single-spaced and never exceed one page in length. The abstract is not an introduction to your paper -- it must stand alone. All of the information in the abstract must also be stated somewhere else in your report.

Table of Contents

Don’t do this section until your entire paper is finished! Make sure the headings and page numbers are correct.

List of Figures

Give each figure in your report a number and a title. For example:

Figure 1: Effect of Temperature on Strength of Aluminum

Make sure the titles in the list of figures match the actual titles on the figures. Give the page numbers for all figures.

List of Tables

Give each table in your report a number and a title. For example:

Table 1: Material Properties for 2024-T3 Aluminum

Make sure the titles in the list of tables match the actual titles on the tables. Give the page numbers for all tables.

List of Symbols and Abbreviations

This section should be included with every technical report, since you will always need to use some symbols and/or abbreviations.
Body of the Report

You will not have a section in your report labeled “Body of Report”! This part of your report will contain various sections depending on the focus of your particular report. The body should always begin with an “Introduction” section and end with a “Conclusions” section.

You might have sections like this, for example:

- Introduction
- Lab Equipment and Procedures
- Results
- Discussion of Results
- Conclusions

Introduction

This section introduces your reader to the topic. Give some background information, your purpose for conducting the work and/or research, and a general idea of what your report will cover. Do not write things like, “We had to do a tensile test for EM 120.” Remember -- make it a report for any engineer to read and get something useful out of. Don’t give any details of your procedures or results in this section.

Lab Equipment and Procedures

Tell how you conducted your test by describing the experiment, test specimens, and procedures used during the experiment. Include a picture or diagram if it will help describe your process. You should also include information on data collection and reduction. Give sufficient background, such as pertinent equations and relationships, so the reader can understand your approach to ‘solving the problem’

Results and Discussion

List your results in a clear, concise format. Use an appropriately labeled table or graph if you have several sets of data. Include relevant observations and discussions that will help the reader better understand your solution process and your end results.

Conclusions

Don’t introduce any new data in this section. Restate the important results and observations in a concise manner. Don’t write things like, “We learned a lot from this lab.”

Make sure you answer all questions and include all data required by your instructor somewhere in the body of your report!
References

This section will have a numbered list of references you used to write your report. Use the format shown in the example report in Part 3 of this guide.

Documentation

Use standard USAFA documentation statements.

Appendices

This is where detailed calculations and/or raw data should go. Don’t put tables and figures here that would be more useful in the text. Make sure you refer to your appendices whenever appropriate within the main text of your report! If you never refer to your calculations, no one will ever look at them.
Part 2 – Formatting Your Report

General

- **Be concise!** Don’t get bogged down in passive voice or use big words to impress. Use just enough words to get your point across clearly.
- **Include page numbers!** The title page doesn’t show a number, but it is page ‘i’. All pages before the body of your report are given small Roman numerals – ii, iii, iv, etc. The “Introduction” should be page “1” and all successive pages (including appendices) also have Arabic numerals – 2, 3, 4, etc.
- Use 1 inch margins for the top, bottom, left and right sides of your report.
- Don’t use anything smaller than 12-point font unless your instructor tells you to.
- The Abstract is always single-spaced. You may choose to double- or single-space the rest of your report. (Double-spaced is easier to grade.)

Table and Figures

- Don’t send the reader all over the place (or to appendices) to find important figures and tables! Incorporate useful figures and tables into the main text of your report.
- For tables, put the number and title directly above each table.
- For figures, put the number and title directly below each figure.

References

- Whenever you say something in your report that you got from a reference, put the reference number and page number at the end of the sentence. Also, put the reference number near any data (such as material properties) you look up. Remember to do this both in the text and in any figures or tables containing data that is not your own. Here’s an example that tells the reader you got your data from reference number 4 on page 256:

  The yield strength of 2024-T3 aluminum is 345 MPa. [4, p. 256]

Calculations

- Don’t include detailed calculations or explanations of calculations in the main text of your report. You may want to put a few key calculations in the text and refer the reader to an appendix for the details.
- If you use handwritten calculations, write them very neatly and then photocopy the page(s) to include with your report. Don’t put pencil calculations in your final copy.
- Draw free body diagrams (FBDs) and other pictures to help the reader understand what you’re doing.
- Include some **words** to explain what you’re doing for each set of calculations.
Engineering Mechanics 3XX

Spring 2000

Tensile Test Lab
(Example Lab Report)

C2C Iam Sharp
ABSTRACT

The tensile test lab was conducted to investigate the stress and strain behavior of four different materials, which were 1018 steel, 1090 steel, 2024-T3 aluminum, and 7075-Txx aluminum (specific heat treatment unknown).

The results of the lab indicated that 1090 steel had a higher ultimate strength and lower ductility than 1018 steel, although the yield strengths were similar. 7075-Txx aluminum was determined to have a T6 heat treatment, and had higher yield and ultimate strengths than 2024 aluminum, however 2024 was slightly more ductile than 7075.
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LIST OF SYMBOLS/ABBREVIATIONS

\( \sigma \) = engineering stress \hspace{1cm} E = \text{elastic modulus} \\
\( \varepsilon \) = engineering strain \hspace{1cm} \varepsilon_f = \text{fracture strain} \\
\( \sigma_o = 0.2\% \text{ offset yield strength} \hspace{1cm} 100\varepsilon_f = \text{percent elongation} \\
\( \sigma_u = \text{ultimate strength} \hspace{1cm} \%RA = \text{percent reduction in area} \\
\( \sigma_f = \text{fracture strength} \hspace{1cm} u_f = \text{tensile toughness} \)
INTRODUCTION

Tensile tests are routinely performed on materials to gain useful material property data that can be used to predict material response to various types of loading situations. The materials investigated in this report include 1018 steel, 1090 steel, 2024-T3 aluminum, and 7075-Txx aluminum (specific heat treatment unknown).

The purposes of this experiment were to:
• Compare the properties of the two steel alloys to each other.
• Compare the properties of the two aluminum alloys to each other.
• Determine the specific heat treatment for the 7075 aluminum.
• Compare experimentally determined properties to those found in reference books.

TEST PROCEDURES

Tensile Test Specimens

All tensile test specimens used were cylindrical with 0.75 inch threaded ends and nominal 0.505 inch diameter over a 2.5 inch gauge length. Each specimen was indented before testing with indent separations of 2.00 inches.

Test Equipment

Standard tensile tests were conducted using a 50-kip capacity SATEC tensile test machine. All tests were done in displacement-controlled mode with all specimens pulled apart at about 0.05 inches per minute. A contact extensometer with an initial separation of 1.0 inch was used to measure elongation. While each specimen was being pulled apart, the SATEC machine automatically recorded elongation and load data in units of inches and pounds, respectively.

Data Reduction

Load data was converted into stress data by using the relationship:

$$\sigma = \frac{P}{A_i} \quad [4, \text{p. 146}]$$

where $P =$ load (lbs), $A_i =$ original cross-sectional area (in$^2$), and $\sigma =$ stress (psi). For this experiment, the original cross-sectional area used was 0.200 in$^2$ for all specimens. Elongation data was converted into strain data by using the relationship:

$$\varepsilon = \frac{\Delta L}{L_i} \quad [4, \text{p. 146}]$$

where $\Delta L =$ elongation (in), $L_i =$ original extensometer separation (in), and $\varepsilon =$ strain (in/in). For this experiment, the original extensometer separation used was 1.00 inch for all specimens.
RESULTS AND DISCUSSION

Two major tasks were accomplished for this experiment. The first was to investigate the tensile behavior of plain carbon steels. The second involved tensile behavior of aluminum alloys.

Tensile Behavior of Plain Carbon Steels

Tensile specimens for both 1018 steel and 1090 steel were tested and stress-strain data generated. Both stress-strain curves are shown below in Figure 1.

![Figure 1: Comparison of Stress-Strain Relationships for 1018 and 1090 Steel](image)

The data from Figure 1 were plotted again to zoom in on the linear region so that a 0.2% offset line could be drawn to find the offset yield strengths ($\sigma_o$) for both materials. The plot is shown on the following page in Figure 2. Calculations used to determine the elastic modulus and offset yield strength values are shown in Appendix A.
Figures 1 and 2 and the data used to generate these curves were used to determine various material properties for 1018 and 1090 steel. These data are compared with published data in Table 1 below. Calculations for percent reduction in area (%RA) and tensile toughness (ut) are contained in Appendix A.

Table 1: Comparison of 1018 and 1090 Steel Experimental Tensile Data with Published Values

<table>
<thead>
<tr>
<th>Material</th>
<th>σ₀ (ksi)</th>
<th>σₚ (ksi)</th>
<th>σₙ (ksi)</th>
<th>E (x 10^6 psi)</th>
<th>100ε₀</th>
<th>%RA</th>
<th>uₜ (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1018</td>
<td>83</td>
<td>96</td>
<td>79</td>
<td>28.6</td>
<td>14.8</td>
<td>54.05</td>
<td>13.25</td>
</tr>
<tr>
<td>1090</td>
<td>84</td>
<td>154</td>
<td>149</td>
<td>30.5</td>
<td>9.1</td>
<td>12.47</td>
<td>10.83</td>
</tr>
</tbody>
</table>

1018* = Handbook values for cold-drawn 1018 steel “Estimated Minimum Values”
1090* = Handbook values for hot-rolled 1090 steel “Estimated Minimum Values”

Table 1 shows that the published strength data for cold-rolled 1018 steel is significantly (about 40%) less than the experimentally measured data. The published %RA is also about 30% less than the experimental value. These differences are most likely because the reference presented “estimated minimum values”. The elastic modulus and percent elongation for 1018 steel are fairly close (less than 8% and 2% different, respectively) to the published values. Table 1 also shows that the published strength data for hot-rolled 1090 steel are lower than the experimental values for the 1090 steel by about 23%. Again, this is probably because the reference used
estimated minimum values. The experimental elastic modulus agreed with the published value. The published %RA was about 67% higher than the experimental value, while the published percent elongation was about 10% higher. It’s possible that the 1090 steel used in the experiment was subjected to some strengthening mechanism that lowered its ductility. No published data could be found for fracture strength or tensile toughness.

Looking again at the data in Table 1, we see that the ultimate strength for the 1090 steel is much higher than that of the 1018 steel. Also, the percent elongation for 1090 is less than that of the 1018. The standard numbering system for steels tells us that 1018 steel has 0.18% carbon while 1090 has 0.90%. We would conclude that increasing carbon content in a steel increases its ultimate strength and decreases its ductility.

Three hardness measurements were taken from each steel specimen, and they are reported below in Table 2. The average of these measurements was used to predict the ultimate strengths of the steels.

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness Values</th>
<th>Avg Hardness</th>
<th>Rockwell</th>
<th>$\sigma_u$ (actual)</th>
<th>$\sigma_u$ (predicted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1018</td>
<td>90.3 90.9 90.3</td>
<td>90.3</td>
<td>B</td>
<td>96 ksi</td>
<td>89 ksi</td>
</tr>
<tr>
<td>1090</td>
<td>25.3 22.9 25.7</td>
<td>24.6</td>
<td>C</td>
<td>154 ksi</td>
<td>121 ksi</td>
</tr>
</tbody>
</table>

The Rockwell "C" scale is used for higher hardness than the Rockwell "B" scale, so Table 2 tells us that 1090 steel is harder than 1018 steel, which means that increasing carbon content increases the hardness of a steel. For both steels, the predicted ultimate strength is not as high as the actual value. The percent error is about 8% for the 1018 steel and about 24% for the 1090 steel, so it appears that the error in predicting ultimate strength based on hardness increases with increasing hardness and the prediction may only useful for steels with low carbon content.

Besides gaining material property data from a tensile test, we can also get some information from looking at the fracture surfaces of the broken specimens. The 1018 steel has a very clearly necked region and a "cup and cone" fracture surface characteristic of a ductile material since the cup and cone exhibit a 45° failure plane which corresponds to the plane of maximum shear stress in a uniaxially loaded specimen. The 1090 steel fracture surface is quite flat and does not show nearly as much necking before fracture. The 1090 fracture is characteristic of a brittle material since it fails on a plane transverse to the loading axis (where maximum normal stress occurs).
Tensile Behavior of Aluminum Alloys

Tensile specimens for both 2024-T3 aluminum and 7075-Txx aluminum were tested and stress-strain data generated. Both stress-strain curves are shown below in Figure 3.

![Stress-Strain Graph](image)

**Figure 3**: Comparison of Stress-Strain Relationships for 2024-T3 and 7075-Txx Aluminum

The data from Figure 3 were plotted again to zoom in on the linear region so that a 0.2% offset line could be drawn to find the offset yield strengths ($\sigma_o$) for both materials. The plot is shown on the following page in Figure 4. Calculations used to determine elastic modulus and offset yield strength values are shown in Appendix B.
Figures 3 and 4 and the data used to generate these curves were used to determine various material properties for 2024-T3 and 7075-Txx aluminum. These data are compared with published data in Table 3 below. Calculations for percent reduction in area (%RA) and tensile toughness ($u_t$) are contained in Appendix B.

Table 3: Comparison of 2024-T3 and 7075-Txx Aluminum

<table>
<thead>
<tr>
<th>Material</th>
<th>$\sigma_o$ (ksi)</th>
<th>$\sigma_u$ (ksi)</th>
<th>$\sigma_f$ (ksi)</th>
<th>E ($x 10^6$ psi)</th>
<th>$100\epsilon_f$</th>
<th>%RA</th>
<th>$u_t$ (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-T3</td>
<td>57</td>
<td>74</td>
<td>70</td>
<td>10.2</td>
<td>17</td>
<td>26.05</td>
<td>11.14</td>
</tr>
<tr>
<td>7075-Txx</td>
<td>75</td>
<td>82</td>
<td>75</td>
<td>9.69</td>
<td>14</td>
<td>24.11</td>
<td>10.99</td>
</tr>
</tbody>
</table>

2024-T3* = Handbook values for 2024-T3 aluminum “Typical Properties”
7075-T6* = Handbook values for 7075-T6 aluminum “Typical Properties”

Table 3 shows that the published data for 2024-T3 aluminum are quite similar to the experimentally measured data, with percent error no larger than 13%. The experimental data acquired for 7075-Txx aluminum had less than 7% difference (except for percent elongation and %RA) with the published data for 7075-T6 aluminum, so T6 is the probable heat treatment used. No published data could be found for fracture strength or tensile toughness for either specimen and no published data could be found for %RA for 2024-T3 aluminum.
Figure 3 and the data in Table 3 show that 7075-T6 aluminum has significantly higher yield and ultimate strengths than 2024-T3 aluminum, but its ductility is a bit lower. This is because 7075 aluminum contains zinc and chromium, while 2024 does not [1, p. 6-23]. Therefore, if strength was the most important feature in a particular design, one would choose 7075-T6 over 2024-T3. However, if a significant amount of plastic deformation before fracture was desired, then 2024-T3 would be the better choice.

As was the case with our steel specimens, we can get more information by looking at the fracture surfaces of the broken specimens. The 7075-T6 aluminum has a necked region and a "cup and cone" fracture surface very similar to that of the 1018 steel, except without quite as much necking. The 2024-T3 specimen also shows some necking, but the fracture surface is quite jagged, with a lot of 45° planes fractured. Since both materials exhibit fracture on 45° planes, they both fail primarily due to shear stress and are both considered ductile materials.

CONCLUSIONS

The original purposes of the lab were to compare the two steel alloys to each other, to compare the two aluminum alloys to each other, and to compare experimental data to those found in reference books.

In comparing 1018 to 1090 steel, 1090 was both stronger and harder, but less ductile, all due to the fact that it has greater carbon content than the 1018 steel. The published strength data found for both steels was listed as “estimated minimum values” and indeed were significantly lower (about 40% for 1018 and about 23% for 1090) than the experimental values.

7075-T6 aluminum was stronger, harder, and less ductile than 2024-T3 aluminum, due to its different alloying elements. The published data for both aluminum alloys were presented as “typical properties” and were very similar to the experimental values.

REFERENCES AND DOCUMENTATION


Documentation: None.
APPENDIX A: STEEL CALCULATIONS

Calculations for the elastic modulus and offset yield strength values as shown in Figure 2:

Figure A1 below was plotted to highlight the areas where the 1018 and 1090 steel curves crossed paths with their respective 0.2% offset lines.

All data shown in Figure A1 were fit with linear trendlines using Excel and equations displayed in Figure A1. The elastic moduli are simply the slopes of the corresponding 0.2% offset trendlines. The intersection of each set of lines gives the 0.2% offset yield strengths, which were calculated by solving each set of two linear equations simultaneously.

For 1018 steel:

\[ y = 28,574,430x - 57,160 \]
\[ y = 4,421,600x + 62,506 \]

For 1090 steel:

\[ y = 30,482,830x - 62,844 \]
\[ y = 4,290,166x + 62,105 \]

**1018 steel**

\[ y = \sigma_o = 83,175 \text{ psi} \]

**1090 steel**

\[ y = \sigma_o = 83,773 \text{ psi} \]
Calculations for %RA and $u_f$ as shown in Table 1:

**1018 Steel**

$D_0 = 0.357''$  $D_f = 0.242''$

\[
\% RA = \frac{A_0 - A_f}{A_0} \cdot 100 \quad [4, \text{ p. 152}]
\]

\[
\% RA = \frac{D_0^2 - D_f^2}{D_0^2} \cdot 100
\]

\[
\% RA = 54.05 \%
\]

$u_f \approx \frac{\varepsilon_f}{2} \frac{\sigma_0 + \sigma_u}{2} \quad [4, \text{ p. 155}]
$

\[
u_f \approx 13.25 \text{ Ksl}
\]

**1090 Steel**

$D_0 = 0.357''$  $D_f = 0.334''$

\[
\% RA = 12.47 \%
\]

$u_f = 10.83 \text{ Ksl}$
APPENDIX B: ALUMINUM CALCULATIONS

Calculations for the elastic modulus and offset yield strength values as shown in Figure 4:

Figure B1 below was plotted to highlight the areas where the 2024-T3 and 7075-Txx aluminum curves crossed paths with their respective 0.2% offset lines.

![Figure B1: Calculation of Elastic Moduli and 0.2% Offset Yield Strengths for 2024-T3 and 7075-Txx Aluminum](image)

All data shown in Figure B1 were fit with linear trendlines using Excel and equations displayed in Figure B1. The elastic moduli are simply the slopes of the corresponding 0.2% offset trendlines. The intersection of each set of lines gives the 0.2% offset yield strengths, which were calculated by solving each set of two linear equations simultaneously.

**2024-T3 Al**

\[ y = 10,242,964x - 20,624 \]
\[ y = 332,782x + 54,164 \]
\[ x = 7.55 \times 10^{-3} \text{ in/in} \]

\[ y = \sigma_o = 56,675 \text{ psi} \]

**7075-Txx Al**

\[ y = 9,688,120x - 19,402 \]
\[ y = 389,385x + 71,040 \]
\[ x = 9.73 \times 10^{-3} \text{ in/in} \]

\[ y = \sigma_o = 74,827 \text{ psi} \]
Calculations for %RA and $u_f$ as shown in Table 3:

**2024-T3 Al**

\[
D_0 = 0.357'' \quad D_f = 0.307''
\]

\[
\% \text{ RA} = \frac{D_0^2 - D_f^2}{D_0^2} \cdot 100 \quad \text{[4, p. 152]}
\]

\[
\% \text{ RA} = 26.05\%
\]

\[
u_f = E \cdot \frac{\sigma_0 + \sigma_b}{2} \quad \text{[4, p. 152]}
\]

\[
u_f = 11.14 \text{ ksi}
\]

**7075-T6 Al**

\[
D_0 = 0.357'' \quad D_f = 0.311''
\]

\[
\% \text{ RA} = 24.11\%
\]

\[
u_f = 10.99 \text{ ksi}
\]