

[http://en.wikipedia.org/wiki/Ambrose\\_Bierce](http://en.wikipedia.org/wiki/Ambrose_Bierce)

Technical writing is the main vehicle by which engineers convey their work to others, such as their bosses, professors, colleagues or regulators. Engineering reports almost always contain original work, i.e., information *created* by the author. This original work may be in the form of laboratory research results, equipment design specifications, material property estimations, or computational simulations, among others. This creative feature distinguishes engineering reports, including those submitted for university coursework, from other forms of technical writing with which you may be more familiar, such as science class lab reports or technology magazine articles.

Because engineering work is creative, it is absolutely essential that the written report accurately and *unambiguously* describe what was done. The quote "Good writing is clear thinking made visible" is especially applicable to engineering reports, although the journalist Ambrose Bierce was referring to non-technical writing. Clarity is the most important requirement for engineering reports. In the interest of clarity, you are allowed to bend rules that were established for other forms of writing, e.g., you may *occasionally* relax the ban on the use of the first person.

Technical engineering reports have a specific format, which is diagrammed in Figure 1 below. This is referred to as the IMMRAD structure, an acronym for the subsections of the main report body (Introduction, Materials and Methods, Results and Discussion). In certain types of engineering documents, an additional special section sometimes follows the Introduction. Examples of Special sections are a Background chapter of a thesis and a Description of Design section of a complex design report. The main body (the blue oval in Figure 1) of the report is preceded by an abstract or summary, but the abstract is always *written* AFTER the main body. Appendices and References are located at the end of the report. This document explains the individual parts of an engineering report.

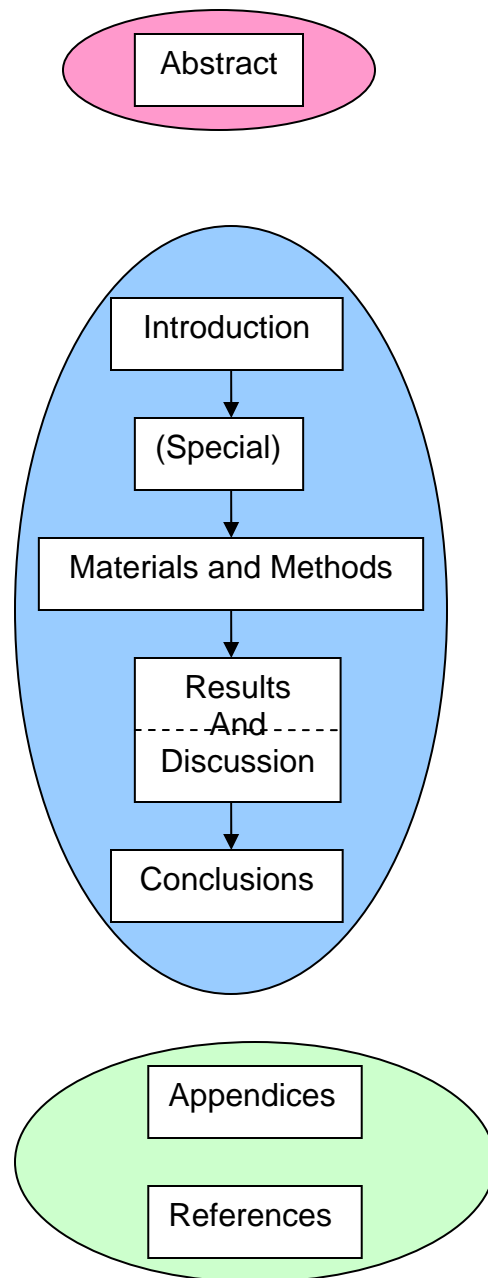


Figure 1. Schematic IMRAD Structure of an Engineering Report

# ABSTRACT

The abstract is a summary of the important contents of a technical report. It is written in narrative form (i.e., as regular paragraphs, NOT “bullet” items). Word limits of 150 or 250 words are common, but even when no limit is specified, an abstract should not exceed 500 words.

People will read your abstract for one of two reasons:

- to determine whether or not they should read the entire report, or
- so they won't HAVE to read the entire report.

Because the abstract is a condensed version of the full technical report, its structure parallels the IMMRAD format.

CHEG recommends that you structure your abstract, in order, as:

- Context
- Objectives
- Approach/Methods
- Results
- Conclusions

This parallels the format established by the Journal of the American Medical Association. For example, see <http://jama.ama-assn.org/cgi/content/abstract/289/1/70>, but DO NOT copy their technique of using incomplete sentences.

Be especially careful that you include engineering *Results* in the Abstract. (Another type of Abstract, sometimes called the “Table of Contents” Abstract, omits specific results, using instead a vague promise that “Results will be presented.” Engineering reports DO NOT use the “Table of Contents” format for the Abstract; specific results must be reported in an engineering Abstract.)

Examples of abstracts illustrated with the Context, Objectives, Methods, Results, Conclusions structure are presented here.

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Below is a 150-word abstract typical of an engineering report in industry:

## **Evaluation of poly(vinyl alcohol) suppliers for glucose sensors**

The number of 1,2-glycol (12G) units in poly(vinyl alcohol) (PVOH) influences the performance of PVOH in glucose sensors under development for use in vivo by diabetics.

This study determined the fraction of 12G units in 10 different samples of PVOH, from 3 different manufacturers, in order to evaluate the suitability of each sample for future study in the glucose sensor development program. The fraction of 12G units was found using periodate cleavage of 12G, followed by intrinsic viscosity measurements of the cleaved fragments. PVOH samples from Chemistor had a significantly higher amount of 12G (3.04% +/- 0.06%) than did PVOH from SuperGoo Scientific (1.91% +/- 0.06%) and PolyMade Inc. (2.02% +/- 0.07%). We recommend that Chemistor PVOH be included in the glucose sensor evaluation program, since it may permit a reduction in sensor size compared with the well-studied SuperGoo PVOH.

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The following is a 250-word abstract from a journal article:

**Drop sizes during turbulent mixing of toluene-heavy oil fractions in water** by Chandra W. Angle<sup>\*</sup>, Hassan A. Hamza, **AICHE Journal** Volume 52, Issue 7, pp. 2639 – 2650 (2006).

“The properties of heavy oil emulsions produced in heavy oil extractions processes often fluctuate, thus making treatments difficult. We investigated whether oil-phase ratios and flow conditions might influence these emulsions. We studied turbulent mixing effects on droplet sizes in real time, using a fully baffled stirred tank with a Rushton turbine in bench-scale batch experiments. Breakup/coalescence of various volume fractions of toluene diluted heavy oil in model process water was measured at four mixing speeds. The range of oil volume fractions was 0.01 to 0.3, where 0.01 is the Kolmogorov limit and 0.3 the upper limit for oil-in-water (O/W) emulsions. Results showed that size distributions depended on mixing time, rpm, and oil fractions. Breakage dominated at low oil fraction 0.01 and high mixing intensities produced bimodal distributions. The persistence of finer droplets was attributed to reduced coalescence. Steady state was not reached. The middle range oil fractions (0.05, 0.1) approached steady state more quickly and followed a first-order breakage model at 800 rpm. The size distributions narrowed before the end of the mixing time. The highest oil fractions and lowest mixing speeds produced the largest droplet sizes. Plots of  $d_{32}$  vs. rpm for 75 min mixing showed that as the volume fraction of oil phase increased the shapes of the curves changed from concave to linear to convex. The  $d_{32}$  vs. energy dissipation curves suggested that turbulent dampening reduced breakage. However, drop coalescence from erosive collisions as well as droplet surface elasticity were factors affecting droplet sizes.”

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An abstract is a self-contained document. That means you must assume the reader has NOT yet read the report, and you may NOT cite external references in the abstract. Likewise, the report itself is a self-contained document, which means you must assume that the reader has NOT read the abstract. If you repeatedly use abbreviations, the stand-alone nature of the abstract and main report means that you may have to define the same abbreviation twice: once in the abstract and once in the report.

Because the Abstract has a word limit, you must select only the most important items (results, methods, conclusions) for inclusion. This selection process requires clear thinking and critical judgment on the part of the author. A “laundry list” of items in the Abstract, although it may indeed be comprehensive and clear, is a sure tip-off to the reader that the author cannot distinguish degrees of importance. Rather than conveying the impression of author objectivity (which may have been the author’s intent), it conveys an impression of ignorance or ennui. Since the Abstract may be your ONLY opportunity to impress a reader (especially those in upper management), you want to be sure to convey a positive impression of the report and its author(s). Hence, spend extra time writing and re-writing your Abstract; this will be time well-spent!

# INTRODUCTION

The Introduction section of an engineering report serves to *introduce* the reader to 3 aspects of the *report* itself:

- |                                    |             |       |
|------------------------------------|-------------|-------|
| (1) the purpose of the report      | (objective) | WHY?  |
| (2) the subject of the report      | (topic)     | WHAT? |
| (3) the organization of the report | (scope)     | HOW?  |

Note that the aspects and questions (What the report is about, Why it is being written, How it is organized) refer to the report itself, NOT to the subject of the report. Often, especially in industrial reports, the question “WHO is the intended audience of this report?” must also be answered. In University of Delaware report writing assignments, the intended audience should be a technically competent generalist, i.e., an engineer who is NOT a specialist in the topic under consideration. Do NOT specify the audience in this case.

The purpose of the Introduction is to orient the reader to your report, so that he or she is easily able to comprehend the rest of the report. Since visual aids help reader comprehension, the Introduction is usually improved when schematic diagrams are added, especially when the report subject matter is relatively complicated.

The Introduction generally begins with a paragraph describing the importance of the subject matter of the report. Next, some background is presented, describing what is already known about the topic. This background should be as BRIEF as possible, and serve only to orient the reader to the rest of the report. (If the background is more than a page or two, you should consider writing an additional section entitled Background; place this section after the Introduction) After describing what is already known or has already been done, introduce what is unknown or what has not yet been done on the topic, and explain why doing this would be beneficial. This directly leads to the objective of the report.

Different reports may vary the order in which the above items are presented, but they should all be located somewhere in the Introduction. The Introduction usually closes with a paragraph indicating what the contents of the following report will be.

The Introduction of a *research* report should ALWAYS contain a concise statement of what you are trying to prove/disprove or determine, i.e., you should clearly state your hypothesis. This is especially true for a thesis document. When you get to the Conclusions section, take care that you conclude whether or not your hypothesis was proven correct by your results. Because of this close relationship between the Introduction and Conclusions, you should always revise your Introduction after you have finished the report. (i.e., after you have written the Conclusions).

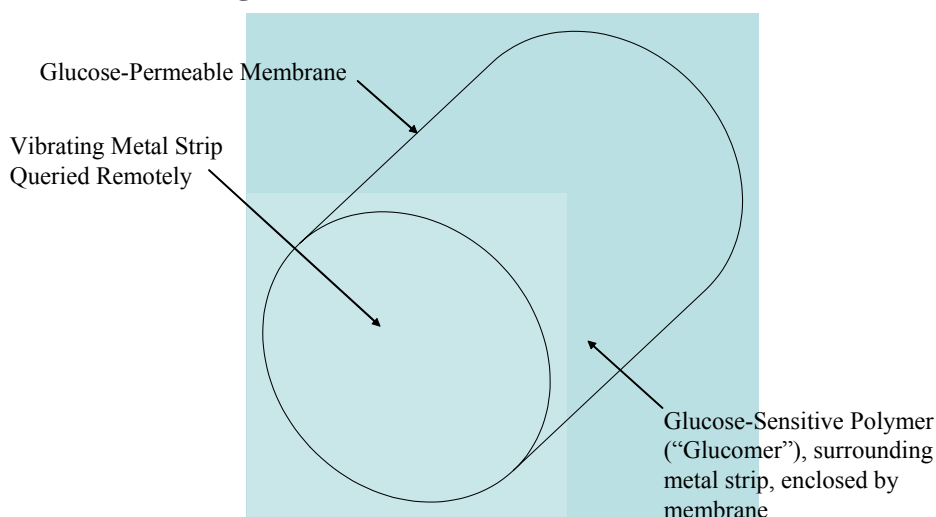
Below is an example of the Introduction from a senior research (CHEG 473/474) report. The color-coding refers to the WHY, WHAT and HOW questions.

## Introduction

The medical device research field is a growing sector of academic and industrial interest, concerned with developing novel and non-invasive devices to administer treatment, monitor, or control of a wide array of human health disorders. Diabetes is a prominent candidate for such a device, since 18.2 million Americans alone (6.3% of the entire population) are diabetic<sup>[1]</sup>. Patients must often prick the surface of their skin to take blood samples to monitor bloodstream sugar levels, and use a syringe injection for the administration of insulin. While some automated devices have been developed for the latter<sup>[2,3]</sup>, a non-invasive device for blood glucose concentration monitoring has not yet been developed. This motivates the focus of this research investigation: to develop an *in-vivo* glucose concentration sensor.

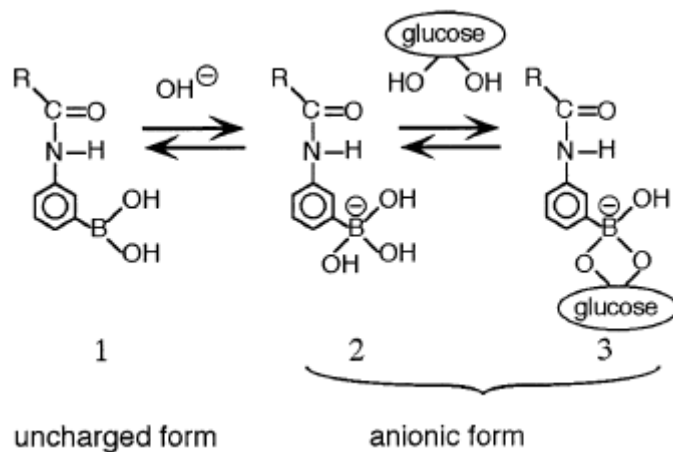
The sensor design proposed here uses a hydrophilic polymer gel medium that swells dynamically and reversibly with changes in glucose concentration. This polymer gel, constrained by a glucose-permeable membrane, surrounds a wireless metal strip through which vibrations are induced by a remote magnetic field. As the polymer gel changes its degree of swelling in response to glucose, the rheology of the gel changes, thereby causing the resonant vibrational frequency of the metal strip to change. The resonant frequency can be measured directly (using a remote sensor) and the corresponding glucose concentration at each frequency value can thereby be determined using an empirical correlation based on experimental data. The specific focus of this investigation is on the synthesis and swelling characterization of the glucose-sensitive polymer, hereafter referred to as the “glucomer.” See Figure I-1 below for a schematic of this proposed device, which ideally would resemble a gelcap-sized pill.

**Figure I-1:** *in-vivo* Glucose Sensor Schematic



The candidate glucomer synthesized and examined in this study is pre-crosslinked polyacrylic acid (PAA) with *m*-aminophenylboronic acid (*m*-APBA) groups substituted onto the PAA backbone. The *m*-APBA is the glucose-sensitive unit; its boronic diol binds reversibly with the *cis*-hydroxyl groups on glucose when in its anionic form<sup>[4]</sup> (see Figure I-2).

**Figure I-2:** Binding between glucomer and glucose<sup>[4]</sup>



The glucomer is then combined with polyvinyl alcohol (PVOH) to form a dynamically swelling interpenetrating network, with PVOH chains wrapped around glucomer chains and crosslinked to themselves to flexibly hold the polymer blend together. When glucose is present at low concentrations in the system, the hydroxyl groups on the PVOH chains also bind reversibly to the *m*-APBA on the glucomer. This dual-binding property of *m*-APBA allows the PVOH-glucomer “crosslinks” to be severed and replaced with glucose molecules, which decreases crosslink density within the system. This in turn allows for more water to swell into the particles. As crosslink density decreases, swelling increases, and vice-versa. Figure I-3 shows pictorially the dynamic effects of glucomer swelling as glucose is added to the system, crosslinks are disrupted, and swelling increases.

This particular glucomer was chosen for a few reasons. Primarily, *m*-APBA was chosen as the glucose-sensing unit due to its successful use in prior studies<sup>[4,6,7,8,9]</sup> on the same subject. Pre-crosslinked PAA was selected for its water affinity and high degree of swelling in water (it absorbs water to 442 times its dry mass). PVOH was selected as an interpenetrating blended polymer due to its successful prior use<sup>[7,10]</sup> in addition to its ease of crosslinking in aqueous solutions<sup>[11,12]</sup>.

Chan<sup>[15]</sup> used a two-step method to synthesize a glucomer similar to the one described here, with slightly different properties. The first step involved the synthesis of a glucose-sensitive monomer, comprised of *m*-APBA attached to a single acrylic acid molecule, termed AAPBA. This monomer was then copolymerized with *N,N*-



dimethylacrylamide (DMA) and N,N-dimethylaminopropylacrylamide (DPA) to form a glucomer with a composition of 10% AAPBA, 15% DPA, and 75% DMA. Chan found that this glucomer qualitatively responded to glucose, but due to time constraints did not crosslink PVOH around his glucomer to determine quantitative swelling characteristics with glucose. An alternate route is taken in this study, since Shimomura et al<sup>[6]</sup> have demonstrated that m-APBA can be chemically synthesized onto PAA in one direct step<sup>[6]</sup>, which is an advantage over Chan's method and others<sup>[4,7]</sup> that require first the synthesis of a glucose-sensing monomer followed by the polymerization of said monomer to obtain a glucomer in final form. A modified form of Shimomura's technique was implemented in this study.

This report includes an explanation of all experimental methods employed to: (1) synthesize the glucomer and glucomer-PVOH network polymer, (2) analyze experimental yields of these syntheses, (3) characterize the glucomer with respect to its degree of swelling and response to glucose, and (4) measure the resonance frequency of a magnetoelastic metal strip in contact with glucomer-PVOH network polymer at increasing glucose concentrations. Quantitative results of these studies are presented, along with a discussion of said results and corresponding conclusions that can be drawn.

### Glucomer in the Presence of Glucose

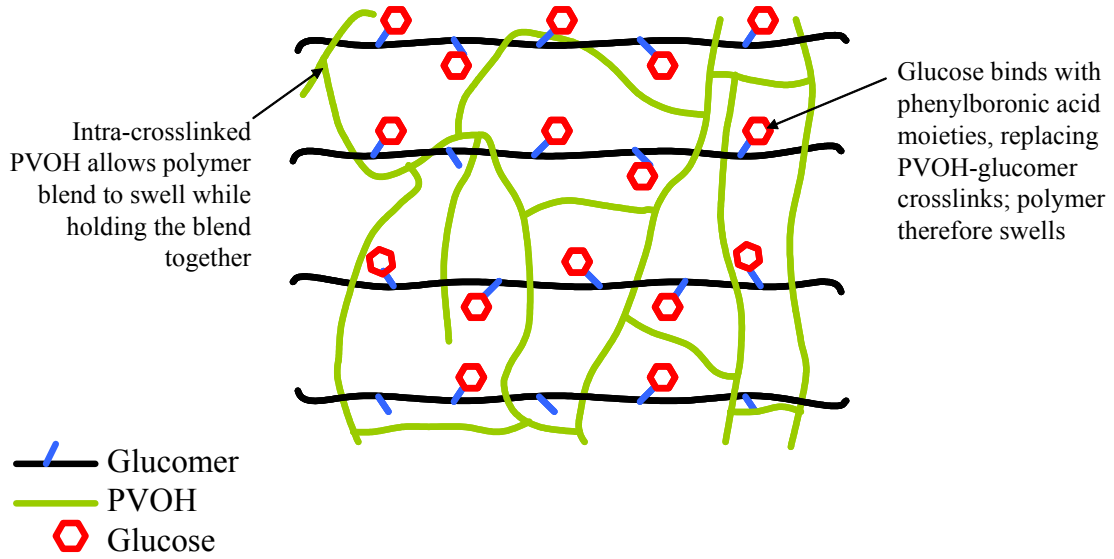
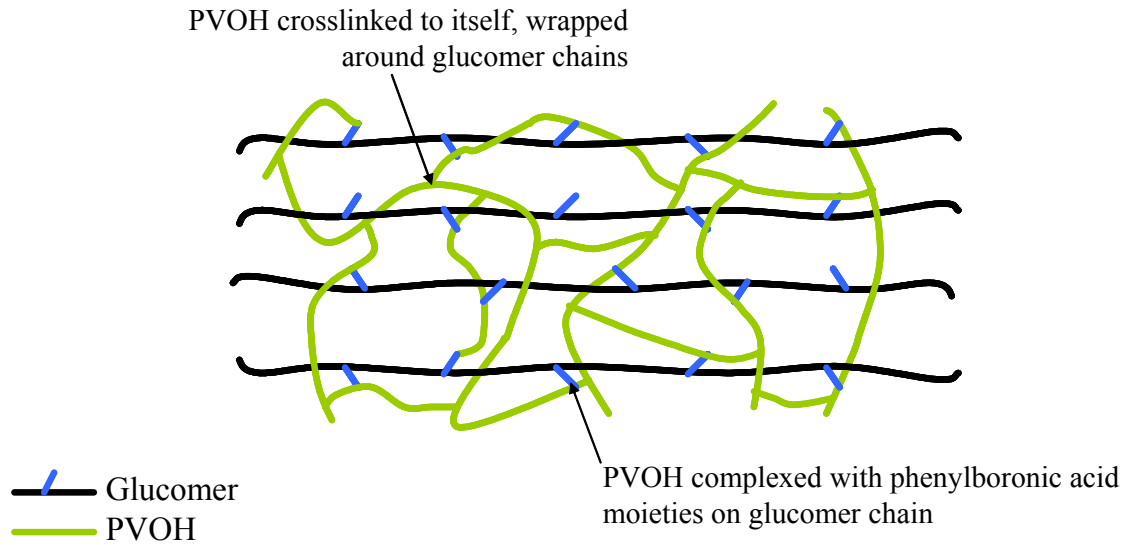


Figure I-3: Glucomer/PVOH Swelling Network

### Glucomer in the Absence of Glucose



## SPECIAL SECTIONS

Two types of engineering documents often deviate from the rigid IMRAD format: theses and comprehensive design reports. In a thesis, including an undergraduate thesis, a Background chapter is frequently inserted after the Introduction, but before Materials and Methods. Few structural rules exist for this Background chapter; its main purpose is to help the students (both the author of the thesis, and future students working on a similar topic) better understand what has already been done. Writing this section often helps clarify the author's thinking, so it may be advantageous to write this section of a thesis first, even before the research has been finished.

Another special section, again inserted after the Introduction, is the Description of Design section used in complex (e.g., an entire chemical plant) design problems, such as those in CHEG 432. An engineering design report must contain a Methods section describing how the design was arrived at, what tools were used, and what constraints were adopted. However, it is very difficult for a reader to digest and evaluate the Methods, without first knowing some specifics of the design. Nevertheless, the actual results of the design are presented in a Results section of the design report, which follows the Methods section. The way out of this Catch-22 is inclusion of a BRIEF (< ½ page of text) description of the design, accompanied by a figure. Good examples of such descriptions (for a chemical process plant design) can be found in the Kirk-Othmer Encyclopedia of Chemical Technology, e.g.,

<http://www.mrw.interscience.wiley.com/kirk/articles/acrylipp.a01/frame.html>

(Click “5. Commercial Processes.”)

# MATERIALS AND METHODS

In the Materials and Methods (M&M) section of an engineering report, you must describe what you did (in the laboratory, or plant, or on a computer) in sufficient detail so that someone who has access to the same facilities could repeat the work exactly. This section should always be written using the past tense, and NOT as “directions.” (Directions use the imperative [command] mode: “After opening the intake valve, turn the pump on.” The ONLY time you may use the imperative mode in technical writing is when the actual document you are composing is an operating procedure. Note that laboratory handouts often include operating procedures, so DO NOT copy the handout procedure for use in your report!) The M&M section is frequently written early, since you know HOW you did your experiments long before you know what your results mean.

## Experimental Methods

Most (experimental) laboratory reports will require you to answer the following questions:

- (1) What were the independent and dependent variables?
- (2) What equipment and materials did you use?
- (3) What was the range of operating conditions?
- (4) What was the reproducibility of the method?

The answers should be provided as precisely as possible. Report the manufacturer and model number of equipment. List the source and lot numbers of chemicals used. When the same measurements are being made on a series of different materials, it is customary to list all the materials in a Table. Report any calibration procedures.

If you simply make a narrated list of everything you did, in the order you did it, you will probably satisfy the absolute requirement of clarity, but it will be excruciatingly boring to read. So, make a special effort to vary your sentence structure when you write the M&M. One way to do this is to include clauses explaining WHY you did things the way you did. (Example: “Reproducibility was established from five repeat measurements in Pipe 3 at a Reynolds number of 50,000, since that was the estimated Reynolds number for the pipeline design project.”) By including reasons, not only will you make the report more interesting to read, you will also make yourself look like a more competent engineer, who understands and intentionally addresses the problems involved in the work.

## Computational Methods

The M&M section is usually relatively easy to write for experimental engineering work, since the author has physically conducted the methods already. However, many engineering reports involve *calculations* only, often conducted with sophisticated software packages. The calculation procedure must also be described in sufficient detail so that a competent engineer with access to the same tools could reproduce your results exactly.

However, many of the same questions should be answered for computational work as for experimental work:

- (1) What were the independent and dependent variables?  
What values did you fix, and which ones did you calculate?
- (2) What equipment and materials did you use?  
What type of computer (model, processor type and speed) did you use?  
What version of commercial software did you use?
- (3) What was the range of operating conditions?  
What range did you specify for input variables, and why?  
What options did you select within the software package, and why?  
What options were set on default, and what was the default?  
How much CPU time did the computations take?
- (4) What was the reproducibility of the method?  
How did you verify that the numerical approximations are correct?

You should present any important equations that were used to calculate values, and include the assumptions which affect the validity of the equations. Simple geometric equations, such as the area of a circle, should not be included. Simple derivations needed to do perform the calculations may be presented in the main text, but more complex derivations, especially those involving extensive algebraic manipulations, should be relegated to an appendix. For equations you have programmed yourself (e.g., in Matlab or Mathcad), or for complex simulations (e.g., Aspen with recycle loops or heat integration), a schematic flowchart should be included. An example of such a flowchart for calculating (in Matlab) the pressure,  $P$ , and specific enthalpy,  $h$ , along the vapor-liquid-equilibrium line, given a temperature,  $T$ , and average density,  $\rho$ , is illustrated in Figure 2 below:

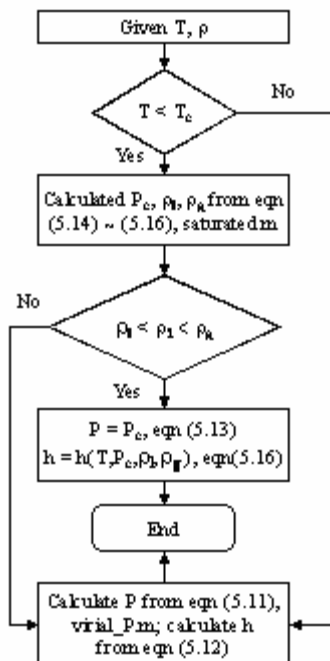


Figure 2. Example of a flowchart for thermodynamic properties calculated using Matlab.

If your calculations involved programming, even if this was done in a simple software package such as Excel, you should include a copy of the program (formulas) in an APPENDIX of the report. DO NOT insert the program into the Methods section. If you used someone else's (non-commercial) program, e.g., if you performed simulations using a program written by a graduate student, then you must include either the program (in an Appendix), or enough information about the program (a reference to the grad student's thesis or publications), so that someone else could duplicate your results.

Below is an example of the Methods section of a student report for a CHEG 341 project involving computational simulations.

**Feed Pipe Diameter Optimization for the Transverse Injection of Ethylene into an Air Stream**, by Jeff Cassel, November 27, 2002

**Engineering Methods**

Two methods were used to solve this problem, one of which was the use of the Forney and Kwon equation<sup>1</sup>. This is a design equation derived from experimental data, and it relates the ratio of the volumetric flow rates to the ratio of the velocities of the injection (side) stream to the main stream:

$$\frac{Q_{side}}{Q_{main}} = \left( 0.11 + \frac{0.60}{R} \right)^2 \left( \frac{1}{R} \right)$$

$Q_{side}$ : side stream volumetric flow rate

$Q_{main}$ : main stream volumetric flow rate

R (velocity ratio of streams):  $R = v_{side}/v_{main}$

The assumptions that take effect when using the Forney and Kwon equation are as follows:

- Side stream to main stream velocity ratio must be greater than 1.
- The only contribution to mixing at point of injection is from side stream turbulence.
- The injection pipe must be centered on the centerline of the main pipe.
- The constants (0.11 and 0.60) were fit to experimental data.
- 

Given the constraints that  $Q_{side}/Q_{main}$  must be equal to or between 1/8 and 1/7, and that  $v_{main} = 1$  m/s, the optimal side stream velocity was calculated for both volumetric ratios. Then the optimal side pipe diameter was calculated, using the general mass balance over the side pipe, as follows:

$$A_{side} = \frac{Q_{side}}{v_{side}} = \frac{\pi}{4} D_{side}^2$$

$A_{side}$ : side pipe cross-sectional area

$D_{side}$ : side pipe diameter

<sup>1</sup>All information on this page from Forney, 623-630, unless noted otherwise.

The second method was the use of *Fluent 5.5*, a computational fluid dynamics software package released by Fluent, Inc. Fluent allowed the user to construct in three dimensions a number of different injection-to-main pipe geometries, and also provided numerical and visual simulations of the flows of air and ethylene. Fluent used iterative numerical techniques to solve a system of equations governing the flow and physical properties of air and ethylene in the system, and outputted exit concentrations of each species as a function of radial position for each case. After defining given constraints (Lobo, 2) such as the composition of air, operating pressure and temperature, air stream velocity, main pipe diameter, turbulent flow parameters for air and ethylene, and the main pipe length after the injection point, Fluent required the input of only one remaining variable to model the situation: the side stream velocity. This was calculated for each geometric and volumetric ratio prior to using Fluent, and then plugged into Fluent one case at a time. A matrix of the cases examined is below in Table EM-1:

The exit plane of the main pipe contained 177 points at which the concentration of each species was estimated (Lobo, 3). To analyze mixing effectiveness for each case, the values for mass fraction of ethylene at each point were averaged, then the standard deviation of the measurements was divided by the average, yielding a statistical term called the coefficient of variation (Lobo, 3). This coefficient quantifies mixing effectiveness by taking advantage of lower standard deviations as the exit concentration of ethylene increases in uniformity, while the average concentration remains relatively constant (due to the law of conservation of mass). This measure of mixing effectiveness

allowed the user to determine the optimum ethylene velocity, which corresponds to the optimum diameter, of the injection pipe.

**Table EM-1: Fluent Case Matrix\***

| Diametric Ratio | Volumetric Feed Ratio | Diametric Ratio | Volumetric Feed Ratio |
|-----------------|-----------------------|-----------------|-----------------------|
| 2:1             | 8:1                   | 4:1             | 8:1                   |
|                 | 7:1                   |                 | 7:1                   |
| 2.5:1           | 8:1                   | 4.5:1           | 8:1                   |
|                 | 7:1                   |                 | 7:1                   |
| 3:1             | 8:1                   | 5:1             | 8:1                   |
|                 | 7:1                   |                 | 7.8:1                 |
| 3.5:1           | 8:1                   |                 | 7.5:1                 |
|                 | 7:1                   |                 | 7.2:1                 |
|                 |                       |                 | 7:1                   |

\*Ratios are in terms of (air:ethylene)





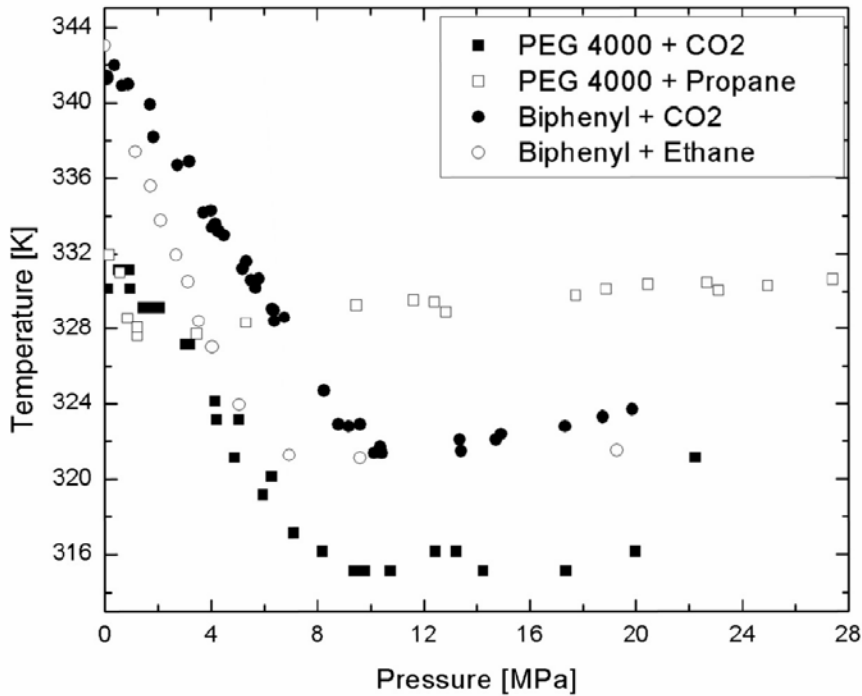
# RESULTS AND DISCUSSION

The Results and Discussion section is the most important part of an engineering report, since it contains the “meat” of the creative work conducted by the engineer. Sometimes this section is written as two separate sections – (1) Results and (2) Discussion of Results, but this is entirely a personal choice. Unless otherwise stated, either combined or separate Results and Discussion sections are equally acceptable for CHEG reports. You may wish to separate the sections if the combined section is exceptionally long, or you may wish to combine them when you have many different *kinds* of results, especially minor results, in which case it is cumbersome to have many short, unrelated pieces of discussion tied together. I (ADS) personally usually combine Results and Discussion together, but you may do whichever you prefer.

## Results

The single biggest mistake that students make in presenting their results in reports is to “dump” the results into figures or tables, without any comments in the text. (e.g., “Results from Pipes 1-5 are shown in Figures 3-7. The individual data points are listed in Table 1.”) Even if you write a separate Results section, you **MUST** include written, textual descriptions of the Results presented in graphs or tables. Only when these comments become a matter of opinion (or speculation or debate), rather than a matter of fact, are the comments classified as “Discussion.”

You should present engineering results in the order: General → Specific, since this order usually corresponds to Most Important → Least Important. For example, suppose that you have measured the melting point ( $T_m$ ) of crystalline compounds as a function of pressure ( $P$ ) in an atmosphere of a pure gas for several crystal/gas combinations. You found that all the  $T_m$  vs.  $P$  curves have a “hockey stick” shape, where  $T_m$  first decreases linearly with increasing  $P$ , and then levels off. Rather than first presenting individual graphs for each crystal/gas pair, and then concluding that all the shapes are the same, you should instead present your first graph which demonstrates the generalization of the curve shapes. An example is given in Figure 3 below:



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Figure 3. Melting temperature of crystalline solids in the presence of a compressed fluid: (■) Poly(ethylene glycol) (PEG) and CO<sub>2</sub>; (□) PEG and Propane; (●) Biphenyl and CO<sub>2</sub>; (○) Biphenyl and Ethane.

The text corresponding to the presentation of Results in Figure 3 should read something like this:

“Experimental  $T_m$  vs.  $P$  curves for poly(ethylene glycol) (PEG) and biphenyl exposed to an excess of a compressed fluid are shown in Fig. 2. Other compounds and compressed fluids showed similar behavior.  $T_m$  initially decreased approximately linearly with increasing  $P$ , followed by a relatively abrupt decrease in slope at a higher pressure. For PEG/CO<sub>2</sub>, a slight increase in the experimentally observed melting temperature was observed at extremely low (but above 0.1 MPa) CO<sub>2</sub> pressures, before the linear decreasing regime began.”

All figures presented in the Results section (or in any other section of an engineering report) MUST have certain attributes:

- (1) All Figures and Tables must be numbered sequentially
- (2) All Figures and Tables must have a caption describing exactly (NOT generally) the contents.
- (3) All graph axes and Table rows/columns must be labeled, including units.

- (4) A legend must identify the symbols used in all graphs. This legend may either be included as a box in the Figure itself, or in the caption. The example Figure 3 illustrates both ways of including the legend.
- (5) All Figures and Tables MUST be referred to by number in the text, and at least one sentence must describe each. If you cannot think of a single original sentence to include about a graphic, it probably does not belong in the main body of your report; put it in an Appendix instead.

## **Discussion**

When you discuss your results, beyond merely describing the contents of graphics, you should do the following, generally in this order:

- (1) Generalize your results. Readers will remember the general rule or observation much better than the individual details.
- (2) Explain possible reasons for the results. It is OK to speculate when you are not sure, but then you must use language (“think,” “believe,” etc.) that reflects this uncertainty.
- (3) Compare your results to literature presented in the Background or Introduction.

It is usually easiest to present these 3 items for each individual result/graphic, before moving on to the next result. If you combine the Results and Discussion sections, you should ALWAYS present Result→Generalization→Reasons→Lit. Comparisons for each result, before presenting the next result.

Note that you should NOT *begin* your results/discussion by immediately comparing your results to literature results, unless your data match exactly what has already been done. If that is the case, then those results probably belong in the Methods section, as a way of verifying the accuracy of your technique. Your original results should be the focus of Results and Discussion.

## CONCLUSIONS

The purpose of the Conclusions section is to summarize whether or not your objectives have been met, or whether or not your hypothesis is correct. This section should NOT present NEW data, interpretations or arguments; those should have been presented in Results and Discussion. To begin the Conclusions, you should repeat the objective/hypothesis, which was presented in the Introduction. Next, identify whether or not the results support the hypothesis. Pretty much, only 3 options exist for this: (1) the data support the hypothesis, (2) the data contradict the hypothesis, or (3) the data are not capable of distinguishing whether the hypothesis is correct or not. Of course, different results may say different things about the hypothesis. Even in cases (1) or (2), where the validity of the hypothesis is clear, the conclusion is restricted to a specific set of circumstances, so you should clearly state those restrictions in the Conclusions. Finally, you should suggest ways to improve your design, experiments or calculations, in order to better satisfy an unmet objectives.

## REFERENCES

Others' work, including Internet resources, must be properly cited in your engineering report. This is done by including "citations" in the body of the report, and listing the complete references to which each citation refers at the END of the report. This section should be labeled "References" or "Works Cited," but NOT "Bibliography." EVERY reference listed in the References MUST have a specific citation in the text, i.e., you may NOT simply list books or articles that you read but did not cite. Because references are listed at the *end* of a document, they are called "Endnotes." This is in contrast to "Footnotes," which are listed at the bottom (foot) of the page on which the citation occurs.

**NOTE:** If you are preparing an "official" document, such as a thesis or a journal article, you should ALWAYS check to see what the required formatting for references is. This guideline is for general-purpose documents, such as class reports.

Unfortunately, there is no single agreed-upon format for citations/references in engineering reports, but the most commonly used format is that of the American Psychological Association (APA). The University of Delaware Writing Center website has an exhaustive treatment of the APA citation style; see

<http://www.english.udel.edu/wc/resource/grammarresource.html>,

and download their 7-page [APA style pdf](#). Similar pages from other universities can also be found online:

[http://www.library.cornell.edu/newhelp/res\\_strategy/citing/apa.html#list](http://www.library.cornell.edu/newhelp/res_strategy/citing/apa.html#list)  
<http://www.liu.edu/CWIS/CWP/library/workshop/citapa.htm>

Descriptions of other styles are also available, e.g.

<http://www.liu.edu/CWIS/CWP/library/workshop/citation.htm>

The APA style cites and lists references by the last name of the first author of the reference. Inside the text, where you are referring to the citation, you insert the author's last name and the year of publication, enclosed in parentheses. That citation in the text looks like this (Shine, 2006). If the name of the author already appears in the text, you simply insert the year in parentheses, e.g., "Shine (2006) recommends you use the APA style."

According to the APA style, the References section at the end of your engineering report should list the references alphabetically. Each periodical reference should contain, in the following order:

Author(s), Year, Title of article, Title of periodical, Volume number, Pages

Acevedo, A., P. M. Cotts and A. D. Shine (2005). "Molecular weight dependence of the rotational diffusivity of rodlike polymers in concentrated nematic solutions." *Macromolecules* 38(15): 6648-6655. DOI: [10.1021/ma048632j](https://doi.org/10.1021/ma048632j)

The sample reference shown above also includes the DOI (Digital Object Identifier) number. This is a number which uniquely identifies the electronic form of the article. By clicking on the DOI, you will be taken directly to the journal article (assuming your institution has paid for a subscription to that journal). When you submit an *electronic* version of your report, it's a good idea to include DOIs in the References, as this will enable your reader (e.g., your thesis advisor) to check your citations and background material.

Properly compiling a Reference list by hand (i.e., without special referencing software) is extremely time-consuming when the number of references is large, say >10. Furthermore, this is usually the last thing you complete in your report before turning it in, so it sometimes gets short-changed in the rush to meet a deadline. If you are writing a research paper with a lot of references (e.g., a real journal article or a thesis), we strongly recommend that you invest in referencing software such as EndNote (<http://www.endnote.com/>). Student versions are \$99, and a free 3-month download is available online. The software can automatically convert reference formats (e.g., between APA style and American Medical Association style) and can automatically upload the formatted citation from a library database (so you don't have to type it in yourself). But perhaps its best feature is that EndNote allows you to store electronic versions (pdfs) of the actual articles within your own "library." This enables you to check the original sources easily.

If you don't want to spring for software, you could try using the built-in endnote features of MS Word. However, this uses numerical citations, rather than the alphabetic APA style. In numerical citations, a number is inserted in the text after the location where the information is cited. The citations are numbered sequentially, beginning with 1, 2, 3 etc. The References are then listed in numerical order in the References section. If the same reference is cited more than once in the text, it should be given the same citation number each time (rather than the next sequential number and an "*ibid.*" reference). Microsoft Word allows you to insert citations numerically; it automatically re-numbers the reference list when you move citations around in the text. (Use Insert→Reference→Footnote→Endnotes. Do a "Help" search for "footnotes" in MS Word to get more information.) Numerical citations are either inserted in the text as a superscripted number (i.e., like this<sup>2</sup>) or else they are inserted inside a square bracket, like this [3]. When you've finished your paper, make sure you increase the font size of the endnotes in your Reference section, so that References are the same font size as the rest of your text.

## APPENDICES

When inclusion of important information within the body of the report would disrupt the flow of report, that information should instead be placed in an Appendix. Examples of items which should properly be located in an Appendix are: Raw data values

- Sample calculations
- Extensive equation derivations
- Programs
- Lists of parameters

Appendices should be sequentially numbered or lettered; Different items should be placed in different appendices. As with figures, tables, and references, EVERY item placed in an Appendix should be mentioned SOMEWHERE in the main text, e.g., “The Matlab program for property calculations can be found in Appendix C.”

If you are unsure whether or not the material should be included in an Appendix, or left out entirely, it usually doesn't hurt to put it in the Appendix. People don't read the Appendices unless they really have to, so extraneous material will not be too offensive in an Appendix.