Chemical Engineering 477
Unit Operations Laboratory II

Winter 2005

T. H. Fletcher
M. J. Beliveau

Class Time and Place: Rm 217 CB, M W 2-5 pm

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Experiments: The experiments attempt to teach our students how to apply the principles taught in previous courses to real process equipment. Problem statements are intentionally open-ended. The students are to plan each experiment, carry it out, and analyze the results.

Communications: Effective communications are essential to a successful career in engineering. Strong emphasis will be placed in this course on written reports. You will also have experience with oral communication.

Procedure: To the extent possible, the industrial environment will be simulated. Assignments will be in the form of a memo from your supervisor. All the experimental work will be performed in class, and you should also try to complete as much data analysis and report writing in class as possible.

Competencies: The competencies defined for this course are included in a table on the last page of this document.

Resource Materials

No official text is used for this course, but information on most of the experiments is available on the course website at http://www.et.byu.edu/groups/uolab/che477.htm. In addition, instruments and supplies may be checked out from the TA. All materials checked out during the laboratory should be returned to the stockroom at the end of the laboratory period. There are also textbooks and engineering handbooks that are kept in the laboratory bookcase for your use; please do not remove them from the room, and please return them to the bookcase at the end of each period. The textbooks from previous courses may also be useful.

Lectures

Brief lectures will be given throughout the semester in 217 CB in order to provide instructions on report writing, data analysis, etc. We hope that these will be helpful and effective. We welcome your feedback, as well as suggestions of topics of interest to you.

Safety

The following safety precautions are required by all (these are not optional):

1. No food is allowed anywhere in the computer or laboratory area.
2. All personnel in the laboratory area are required to wear safety glasses, long pants (no shorts), and covered shoes (no sandals).
3. In addition, all students are required to complete the HAZCOM training course, available in 4733 HBLL, before the beginning of the second class period (if you have already completed the course within the last 2 years, you will not be required to repeat it).
4. Experimental work should be completed during the regular class periods. If additional time is needed, you must clear it with your instructor and make an appointment for the use of the laboratory with Mike Beliveau. At least two partners must be present during those additional hours (no one is permitted to work in the lab alone).

Prerequisites

You should have completed Stat 361 and be able to use the experimental design techniques and basic statistics learned in that course. You should have also completed ChE 373, ChE 374, ChE 376, ChE 476 and ChE 478. It is also assumed that you have successfully completed ChE 475, which is the primary vehicle for instruction on lab report writing. If you have not taken ChE 475, permission must be obtained so that additional instruction can be arranged.

Attendance

In keeping with the goal of simulating the professional environment, you must be in attendance ("at work") for the entire lab period on each day of the lab. For emergencies or other pressing circumstances, please communicate with your instructor, just as you would with an employer. All the experimental work will be done in class, and you should also try to do as much data analysis and report writing in class as possible.

Projects

You will be assigned three projects during the term. Each project will include the following elements:

1. You will be assigned to a team of 2-3 students for each project. It is expected that team members will work cooperatively, each sharing a fair portion of the workload. You will be responsible for evaluating each member of your team at the end of each experiment.
2. Your team will be required to formulate a plan for accomplishing the required task(s) and to present your plan to your instructor in an informal oral presentation during the second period scheduled for a particular experiment.
3. Each student will maintain an individual record of the experiment in a separate laboratory notebook. You will write your own report, in which your own thinking and analysis are a major part and for which you will assume total responsibility. You may share appendix materials with your group, such as charts, mathcad pages, and derivations.
4. You will individually write a final report for each of the projects. For the first project, the report will be a short 3-page report. For the next project, a 7-10 page report will be required. Both a one page memo report and an oral report will be required for the final project. The format for each of these is described elsewhere in your course documents.

Laboratory Notebooks

All pertinent details of each experiment are to be recorded in ink in the laboratory notebook. This should be a bound notebook; spiral notebooks are not acceptable). The details should include but not be limited to the following:

1. Dates and times when experimental work was being performed
2. Names of team members performing the experimental work (all team members must sign notebooks at the end of each day's entry)
3. Specifications of the equipment used (including the settings at which the experiments were performed)
4. All raw data taken by hand
5. Calculations showing reduction and transformation of pertinent data
6. Error analysis on the instruments and data
7. Instrument calibrations
8. Summaries of final data.

Photocopies of key graphs, equipment specifications, tables, data taken by computer, etc., may be carefully taped to a page of the notebook. Completeness and neatness of the project notebook will be a part of your grade. If questions arise about the accuracy and validity of the data in your reports, it should be possible to answer those questions by referring to the project notebook.

Preliminary Reports

Each team must prepare and present a written PRELIMINARY REPORT to the professor before proceeding with the experiment. This report should consist of a diagram of the apparatus plus a short (1 page maximum) summary of plans for the experiment including:

1. Identification of the problem that you are trying to solve
2. An approach to solution of the problem:
    a. Proposed experimental measurements
    b. Data analysis (including a sample calculation!!)
    c. Method for establishing credibility of the data
    d. Expected results (e.g., expected trends)
    e. Strategy to arrive at a recommendation/conclusion
3. Safety considerations

The written portion of the preliminary report should be handed in by the end of the first lab period. An oral summary of the report (5 - 10 min, visual aids not required) will be required during the 2nd lab period of a given experiment. At this time each team member should be prepared to answer questions regarding the experiment, including operation of the equipment. If there are any unresolved questions/concerns about the experiment, you may want to bring them up for discussion during the oral portion of the preliminary report.

Written Reports

Written laboratory reports will be due at the beginning of the lab period when the next experiment is scheduled to start. You should let the instructor know immediately if circumstances arise that prevent you from submitting your report on time. Otherwise, it is expected that your reports will be turned in on time.

Oral Reports

Time will be scheduled during lab for the presentation of oral reports. Approximately 15 minutes should be used to present the material, allowing 5 minutes for the class to ask questions. All team members must participate in the oral presentation and the question and answer session. Grading will be done by both the professor and the class members. The final grade for the oral report will be determined by proportioning both the professor's score and the average of scores given by class members. Timing of an oral report is very important. All team members receive the same point score. The students presenting reports are expected to dress as Professional Engineers, i.e. Sunday best, during their presentation.

Minimum Report Standard

Any laboratory report graded "not acceptable" must be rewritten and resubmitted, or presented a second time in the case of oral reports.

Grading

Short Report	(1^{st} experiment)	25%
Formal Report	(2^{nd} experiment)	30%
Memo Report	(3^{rd} experiment)	10%
Oral Report	(3^{rd} experiment)	10%
Preliminary Reports		5%
Partner Eval., Professor Eval., Attendance, Notebook, etc.		20%

Classroom Etiquette

There is a great deal of freedom in this laboratory class so that students can work on more open-ended problems. Unfortunately, some students have used this lack of structure to be very disruptive to other students working in the laboratory or on the computers. Please be considerate of other people that are trying to work hard in the lab. Up to 5% of the grade will be deducted from students that routinely disrupt the classroom atmosphere in the lab.

Dress and Grooming Code

All of us have been instructed on the Honor and Dress and Grooming Codes of the university. We have all committed to obey and sustain these codes. It will be expected in this class that each of us will honor the commitments that we have made. The teacher reserves the right to ask an individual to leave the laboratory who is failing to abide by his or her commitment to the Dress and Grooming Codes.

Honor Code

The honor code requires students, staff and faculty at BYU to adhere to a high standard of honesty and integrity. One of the key applications of this code is that each student's work must represent his/her own thinking, labor, and understanding. The following points are included in order to clarify how this principle applies to this particular course.

1. The purpose of this course is to help students learn how to perform experiments and document those experiments in well-prepared reports. Therefore, use of previous lab reports written for ChE 477 is strictly forbidden. In other words, there is no situation in which a

student is justified in reading or using a ChE 477 report that was written by someone else. Both the student using the report and the student who supplied the report would be in violation of the honor code.
2. Oral discussions with current or former students regarding ChE 477 are permitted, as long as no previous lab reports are involved. You may also ask other students for suggestions on writing reports.
3. Each report handed in should represent the work of the individual student whose name appears on the report. Paraphrasing portions of a partner's report is not acceptable.
4. Laboratory groups are designed to work together. Consequently, each group should gather, evaluate, and process data together. Discussion and development of a strategy for completing the assigned lab should be performed jointly.
5. Each group may share a common appendix, including figures, tables and sample calculations. However, each student using the appendix should have contributed significantly to the material contained therein, understand the material, and be convinced that it is correct. Note that group members are not required to use a common appendix.
6. It is important that each student learn how to logically and effectively present the results of his/her experiment(s). Therefore, all of the text, figures, and tables used in the body of the report must be the work of the student writing the report. The only allowable exception to this policy is that students are permitted to use the diagrams of equipment from the UO Web page in their reports.
7. Use of data that were not taken by your laboratory group is strictly forbidden. Fabrication of data in any way, shape or form is also forbidden.

If you have any questions as to whether or not a particular action is allowable, please ask the instructor.

Preventing Sexual Harassment

Title IX of the Education Amendments of 1972 prohibits sex discrimination against any participant in an educational program or activity that receives federal funds. The act is intended to eliminate sex discrimination in education. Title IX covers discrimination in programs, admissions, activities, and student-to-student sexual harassment. BYU's policy against sexual harassment extends not only to employees of the University but to students as well. If you encounter unlawful sexual harassment or gender-based discrimination, please talk to your professor; contact the Equal Employment office at 422-5895 or 367-5689 (24-hours); or contact the Honor Code Office at 422-2847.

Students with Disabilities

Brigham Young University is committed to providing a working and learning atmosphere that reasonably accommodates qualified persons with disabilities. If you have any disability that may impair your ability to complete this course successfully, please contact the University Accessibility Center (422-2767). Reasonable academic accommodations are reviewed for all students who have qualified documented disabilities. Services are coordinated with the student and instructor by the UAC. If you need assistance or if you feel you have been unlawfully discriminated against on the basis of disability, you may seek resolution through established grievance policy and procedures. You may contact the Equal Employment Office at 422-5895, D-282 ASB

UO LABORATORY EXPERIMENTS

Students often get the erroneous impression that preparation of a good laboratory report is somehow disconnected from the performance of the experiment. An experiment that is poorly designed, carried out and/or analyzed will not result in an acceptable report. In contrast, a well-performed experiment is straightforward to document in an engineering report. Consequently, proper design, performance and analysis of the experiments are critical to the preparation of an effective laboratory report. The following is a list of items that may be useful as you approach a new experiment.

A. Experimental Design
   1. Plan ahead: What does the theory tell you to measure?
   2. What equipment is available?
      a. What range of conditions will it provide?
      b. Calibrate/check it (don't trust anybody!)
   3. What magnitudes of values do you expect to measure?
   4. What magnitudes of error do you expect?
   5. How much time is needed to reach steady state?
   6. What conditions (values of the variables) should you examine?
   7. How many replicates should you run? What order?
   8. How will you use these measurements & analyses to answer the question at hand?

B. Performance of the Experiment
   1. Has the apparatus reached steady-state (if applicable)? How do you know?
   2. Have you recorded the settings at which the experiments were performed?
   3. What observations did you make? Are they recorded in your lab book?
   4. Have you analyzed data before "completing" the experiment? It is wise to process data as soon as possible to make sure that your experiments are being performed properly.
   5. Have you observed any systematic changes from day to day? Do the results depend on the order in which the data were taken?
   6. Are the results reproducible? If not, why? Can a change be made to correct the problem?
   7. Are the observed trends consistent with expectations?
   8. Have you explored the range of data possible? Are the observed changes significant?

C. Experimental Results and Analysis
   1. Think carefully--does that equation apply here?
   2. Error analysis:
      a. Standard deviations/confidence intervals
      b. Are differences significant?
   3. Compare with theoretical predictions, others' results, common sense
   4. Evaluate suspected influence of unintended effects
   5. What conclusions can be drawn from the data? Is the quality of the data sufficient to support the conclusion(s)?

WRITTEN REPORTS

Many industrial executives state that the greatest weakness of most young chemical engineers is their inability to report clearly the important results and conclusions of their work. This weakness frequently results from a combination of poor grammar, weak logic, hazy thinking, and carelessness.

The importance of learning never to allow a carelessly written letter, technical paper, or report to leave your possession cannot be overemphasized. In industry the greater part of your contacts with superiors will come through writing rather than through personal contacts. Frequently these people will know nothing more of your character, ability, and appearance than they can deduce from your correspondence and reports. Regardless of a person's ability, it is only after the chance to demonstrate it has been secured that it becomes of value. Good work poorly presented loses its force, and in selecting from a group for promotion, those engineers will be advanced who give the most promise of reliability and thoroughness in their correspondences.

While no pretense is made that the methods presented are the only acceptable forms, the student will be required to follow them. This may seem arbitrary, but is designed to help you learn that in industry your reports must conform to the requirements of your employer. You have been given a sample report to illustrate the desired format for the formal report.

The purpose of reports is to convey information to the reader, and to convince him/her to accept your conclusions and recommendations. You must be clear, concise, and factual, have your conclusions and recommendations in mind before you begin writing, and structure the whole report to make them convincing. It may help to make a detailed outline before beginning any writing. The mere taking and reporting of data is insufficient; intelligent interpretation must be included.

Four different types of reports are discussed in the paragraphs that follow. These are the reports that we will use in this class.

FORMAL REPORTS

Formal reports are usually written at the conclusion of a project. A formal report may be indexed, put in the company library, and become a permanent documentation of your achievements for widespread distribution. Copies may be sent throughout the corporation to persons who are aware of the project and want to know what you found. The formal report is also used by people who want to continue your work elsewhere in the company. The report should contain enough information so that someone can reproduce what you have done. At the same time, the report should not be so long that people cannot find the key results.

Formal reports for Chemical Engineering courses should usually contain the following sections:

1. Letter of Transmittal
2. Title Page
3. Abstract (or Summary)
4. Introduction
5. Background
6. Description of experimental apparatus and procedures
7. Results, Analysis and Discussion
8. Conclusions and Recommendations
9. Acknowledgments
10. References
11. Appendices
    (a) Tables of data
    (b) Sample calculations
    (c) Nomenclature
    (d) Calibrations

Reports should be as brief and to the point as possible. **Sections 4 through 8 should be limited to ten double-spaced pages of text, including figures and tables.** Other material may go into the Appendix. Excessively long reports may receive a reduced grade.

1. Letter of Transmittal. This states who authorized (or ordered) you to do the project, when this occurred, and the nature of the project, and that your formal report for the project is attached. You keep a copy of the letter, as your proof of delivering the report. This letter may be informal in style, but it is usually very short, say one paragraph. Some writers like to add a few sentences to call special attention to some special result in the report. This is probably a good idea.

2. Title Page. This shows the title of the report, the authors, the name of the organization, and the date. It should look nice, like the title page of a book.

3. Summary (Abstract). This is the most important (and often the most difficult to write) part of the report. You should realize that some readers to whom your formal report is sent will read the Summary and nothing else! Be sure it can stand alone. State the object of the work and justification for doing the work. Define the scope of the work. Give a brief, accurate description of the apparatus and procedure. State your principal results and conclusions. Finally, state the importance or significance of your findings. Do not use subheadings in the Summary. The usual length is one page. It is usually wise to write your Summary last, although it appears near the front of your report.

4. Introduction. The purpose of the Introduction is to orient the reader. You should briefly describe the purpose, justification for, and scope of your study. Also, a sentence or two describing the organization of the report is often useful.

5. Background. Use the section to provide the reader with essential background information. Refer to any theory or equations that you intend to use, but do not copy derivations

from standard textbooks. Also, you should show your reader that you are familiar with what others have done, what has been published in this field, and how it is related to your work.

6. Experimental Apparatus and Procedure. Describe your apparatus and procedure in this section. The apparatus should be described in sufficient detail so that a reader can duplicate your set-up and run his/her own tests. Give dimensions, materials of construction, and name-plate information as applicable. Describe the experimental procedure in sufficient detail so that a reader can repeat your experiments if so desired. An annotated schematic diagram of apparatus is helpful. Do not use a diary or journal style, because diaries often include unimportant things. Use verb tenses that will be correct when the report is read. **Nearly always this means that the past tense is correct**.

7. Results, Analysis, and Discussion. This is typically the longest and most substantial section of the report. Present your measured results in a logical fashion in order to support your conclusion(s). Refer to each table and figure, and state explicitly what you want the reader to notice. Establish the credibility of your data from the results of your error analysis. Tell whether your results agree with prior work. Explain your results and account for discrepancies with accepted or expected results. Make sure that explanations are based on data and analysis rather than conjecture.

8. Conclusions and Recommendations. This section should be more than just a summary of what was accomplished, although a brief summary is applicable. Rather, the focus should be on the significant results and why they are important. The conclusions are sometimes expressed as a set of numbered sentences where each item is a conclusion. Your conclusions should relate to the stated objective(s) of your work. The number of conclusions is usually rather small. A recommendation for action based on your conclusions should be made when appropriate. Additional recommendations that are definite proposals for studies of new variables, extending the range of variables, changes in equipment, or other proposals for future work may also be made. Caution is advised. A recommendation that the study should be redone correctly is not advisable.

9. Acknowledgments. Express appreciation for those who helped you. This is a courtesy and helps secure future assistance.

10. References. List every document that you referred to in the body of your report. In the body these are usually given a number such as (1). The same number is used in the list of references. Be sure each reference is complete: title of book, journal, or reprint; authors; title of the article; inclusive pages; date; volume number. Do not list documents which are not referred to in your report. Below are typical formats for references which are (1) a book, (2) a journal, (3) a report.

(1) Treybal, Robert E., Mass Transfer Operations, 3rd ed., p. 409, McGraw-Hill, New York, (1980).

(2) Grossman, I.E., and Sargent, R.W.H., "Optimum Design of Chemical Plants with

Uncertain Parameters," AIChE Journal, 24, 1021-1028 (1978).

(3) Polomik, E.E., "Transition Boiling Heat Transfer Program," General Electric Atomic Power Report 5563, p. 24-28 (October 1967).

11. Appendix. Your formal report must contain your data and your results. Usually these are given in the Appendix as Tables of Observed Data and Tables of Calculated Results Data. Give a title and a table number to every table. Operation data including experimental settings, temperature, etc. should also be included.

Supporting figures which are not directly discussed in the text should be included in the Appendix. Give a title and a figure number to every graph.

Give one set of Sample Calculations: choose one set of experiments, list all the observed data, and show how you converted those data into your final calculated values which appear in your graphs and elsewhere in the report. The Sample Calculations should be checked with extreme care so that they are free of errors. An error in your sample calculations makes all of your results and conclusions questionable. Sample calculations should be handwritten or prepared with a program such as Mathcad so that they can be clearly followed. Sample calculations should not be prepared with a spreadsheet.

Symbols will be used. Give a Table of Nomenclature that defines every symbol used in your report.

SHORT REPORTS

The short report, or extended abstract, communicates your results to the people who will use them. These reports may be circulated in the form of a letter or company memo. You must include sufficient detail so that another engineer can use your data to design a process or a new piece of equipment, but be concise enough that the design engineer does not have to hunt for the results he needs.

The organization of a short report is much like that of an abstract. Start with a sentence or two describing the objective of your work, and what you did to accomplish this objective. Present what you found. Provide graphs showing your key results. Discuss your results in concise detail, observing key trends and comparing your results with what was expected. Finally, conclude by saying what your results mean.

The short report should contain approximately 3 pages of text (double spaced), including figures and tables. No letter of transmittal is needed. Clearly, you will be required to carefully choose the information that you include in the report as the length is quite limited. An appendix similar to that used for a formal report is also required.

MEMO REPORT

A one-page memo report will be required for the third experiment. This report is essentially an abstract and should following the guidelines outlined previously for abstracts. No figures

should be included in the report. One table is allowed (not required), provided that the one page restriction is not violated. A full appendix is required.

ORAL REPORTS

The required preparation for an oral report is as extensive as, if not more so than that required for a written report. The engineer must be thoroughly familiar with his/her experiment and results and must be able to respond immediately to questions from his/her listeners.

Figures and tables should be prepared on view graphs to assist in the presentation. These must be neat and easy to understand. They must be clear, and readable from the back of the room. When you present your oral report to the class, you should include a diagram of your apparatus, summaries of your data, and graphs and figures of your results. You should be prepared to answer questions from the listeners, to demonstrate sample calculations, explain applicable theory, to explain your experimental procedure and results, and to justify your results and conclusions, much like you would in a written report.

FORMAT ISSUES

Your report should be on plain white paper (double spaced), and the pages should be numbered. You are not required to submit the report in a folder for this class. A word processor is always used in industry and is required in this course. Reports should be printed in a 12 point font with 1 inch margins.

Other format issues include the following:

1. Make sure to refer to each figure and table that is included in the body of the report. Additional figures and tables should be put in the Appendix.
2. A properly prepared figure should stand alone. A descriptive caption should be included at the bottom of the figure (not at the top!). Figures should be numbered sequentially throughout the report, and should appear after they are referenced in the text (see model report).
3. Equations should be separated from the text and should be numbered (see model report).
4. Lists should be used freely. The above suggestions are easier to read as a numbered list than they would be if strung together in one long paragraph. The same is true of many parts of an engineering report. The use of lists greatly aids the reader.
5. Your document should not contain spelling or grammatical errors. These are a sign to the reader that you have not taken proper care in preparation of the document, and they infer that the study was probably performed in a similar fashion.
6. Units are very important. Make sure that you use a consistent set of units. Do not switch back and forth between English units and SI units.
6. Precision is an important element of technical writing. Just because you intended a sentence to say one thing, there may be alternate interpretations. Clear writing leaves no ambiguities. Also, try to say things simply. After you have completed a draft of your report, edit it to improve the precision. Below are a few examples of the types of changes

that might be made (from K. Solen):

Replace:	**With:**
during the course of the experiment	during the experiment
corrosion which was there because of the acid	acid-induced corrosion
We were able to measure...	We measured...
We found out that the flow rate was...	The flow rate was...
calculated the mass transfer coefficient	The mass transfer coefficients from
Our biggest problem was...	[nothing]
from equation 4, and the results are shown in Figure 3. The values increased with increasing Reynolds number.	equation 4 increased with increasing Reynolds number (see Figure 3).
a tall spray dryer	a 40-foot tall spray dryer
a long, thin pipe	an 85-foot long 3-inch diameter pipe
results agreed fairly well with predictions	results fell within 7% of predictions
efficiency was low	efficiency was 41%

Grading reports is very subjective to the style of the professor. I do not know a way to make this more objective. Here are some of the commonly-made writing errors that will affect your grade:

1. A dangling prepositional phrase, i.e., a prepositional phrase followed by a conjunction.

Example: *The reactor was filled with iso-propanol and water was used to cool the vessel.*

Here, "with" is the preposition, and it is not clear if the word "water" is part of the prepositional phrase or not! Solution: Use a comma to distinguish the end of the prepositional phrase:

The reactor was filled with iso-propanol, and water was used to cool the vessel.

2. Run-on sentences. If your sentence contains three or more lines, it is probably too long. Break it into 2 or 3 sentences.

3. Choppy sentences. Look to see if there are too many commas in your sentence. Sometimes this type of sentence can be rearranged by putting the last phrase at the beginning of the sentence to eliminate commas. Put the most important part of the sentence at the beginning, if possible. Ask yourself, "What am I really trying to say?"

4. Third person. The short report and formal report will be in third person. The memo report can use first person.

5. "Work (or experiments) was done…" This makes the word "done" ambiguous. The reader is not sure if the work was completed or merely performed. Please use "performed" instead of

“done.”