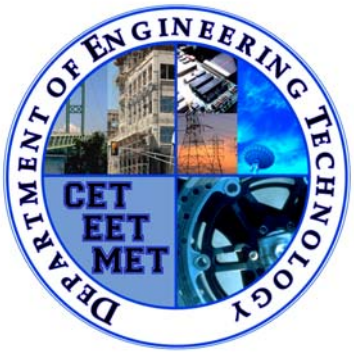

Laboratory Manual

Principles, Procedures & Reporting

THE METROPOLITAN STATE COLLEGE *of* DENVER
Department of Mechanical Engineering Technology

Table of Contents

1 Introduction

This lab manual is common to all programs within Mechical Engineering Technology at Metropolitan State College of Denver. Students are encouraged to learn to do all experiments following the same general methods and procedures presented in this manual, and to document them in lab reports using similar styles and format. This will help perfect laboratory and reporting skills useful for students to professionally integrate into industrial or research laboratory establishments. An example being the learning of LabView to create virtual instruments for data acquisition.

The exercises in this manual are designed to give engineering technology students an introduction to laboratory procedures for performing experiments in fluid mechanics, thermodynamics, heat transfer, strength of materials and other mechanical engineering subjects. The purpose is to provide students with a deeper understanding of theoretical principles by observing phenomena, by measuring physical characteristics and by comparing measured versus calculated results. This “hands-on” experience is essential to an engineering technology student.

Each assigned lab experiment (individually separated by dividers in this ring binder) is prefaced by briefly presenting the theory and the physical principles that will be demonstrated experimentally. Although material relevant to the lab is discussed in class, the lab manual will sometimes provide supplemental material that could not be covered in class because of time constraints. Thus by reading the lab manual and by performing the lab exercises, the student will gain a much greater knowledge of basic principles than could be obtained by attending lectures, reading the textbook, and working homework problems only.

These exercises are also intended to teach students the principles of laboratory protocol and reporting. In addition to following the procedures given for a lab, each student will be required to submit a lab report documenting the experiment and the results. Documenting laboratory results in a clear and concise manner is just as important as conducting an experiment properly. The laboratory discipline and the reporting principles presented herein will extend directly to any engineering test lab in industry. The suggested format for the lab report is provided in Section 4 of this manual. Students are expected to submit neat, professional reports, free of grammar and spelling errors.

Usually experiments have been performed and validated by the MET department during the preparation of this manual. Such experiments are often documented by detailed test plan-like procedures. When these are followed, the students can expect to complete the lab within the allotted time, and obtain the expected results. In such cases, deviations form the procedures will not be permitted. Other times relatively new experiments are introduced which have not been matured by numerous student trials here at Metro. For these, only the goals of the experiment

are documented along with a description of the apparatus to be used, and the student teams are expected to improvise test procedures appropriate to achieving the stated goals. These two possibilities will be clear from the experiment writeups themselves.

2 Laboratory Procedure and Control

A goal of the Mechanical Engineering Technology Department is training students to work well in teams in the pursuit of a common objective such as a lab experiment. Thus students have to learn to organize themselves into team groups, and to allocate responsibilities among themselves. In some cases an individual will assume a leadership role, while in other instances the same student will take a subordinate position. Students are encouraged to become useful in both of these activities.

2.1 Laboratory Teams

A team consisting of 3 to 5 students will perform each experiment. Prior to beginning an experiment, the team shall select one Test Conductor, at least one Data Recorder, and at least one Test Technician to operate the equipment in accordance with the operations specified in each procedure. Additionally a Test Documentor will be chosen to take digital photographs and to create a video record of the experiment. Roles and responsibilities are as specified below.

2.1.1 Test Conductor

When a lab experiment is associated with a detailed test procedure, the Test Conductor (TC) will be responsible for ensuring that the procedure is followed as specified. Each step shall be read aloud to the team prior to performing it. After verifying completion of the step, the TC shall indicate completion by initialing in the space provided next to the text of the step. The Test Conductor will control the procedure at all times. The Test Conductor shall provide copies of the as-run procedure to each team member after completion of the experiment. As-run procedures shall be included as an attachment to the Lab Report.

When a lab experiment is documented more generally in terms of an overall objective as applied to an apparatus, the TC shall lead a team effort to accomplish the goals of the experiment using the apparatus as specified and within the constraints of time and available methods. In these instances, the TC will record experiment progress in an as-conducted test procedure which will be distributed to the team and included in the Lab Report.

2.1.2 Data Recorder(s)

When data must be recorded manually, the Data Recorder (DR) shall be responsible for filling in the Test Data Sheet or its equivalent. It is recommended that when possible, two team members serve as Data Recorders. The Data Recorder is responsible to make copies of completed Data Sheets available to the team members after completion of the experiment. The DR shall also ensure that data generated by test instrumentation (strip charts, printouts, etc.) are copied and made available to the team members. Copies of Data Sheets and printouts generated by test instrumentation shall be included in the Lab Report.

2.1.3 Test Technician(s)

At least one person, but usually two, shall serve as the Test Technician (Tech). Techs shall perform any manual operations of test equipment or reading of instrumentation that is specified in the test procedure (e.g., opening/closing valves, reading temperatures or pressures, etc.). It is strongly recommended that at least one other person, either a Data Recorder or a second Tech, verify an instrumentation reading by making a second, independent reading. Any discrepancies should be resolved before continuing to the next step of the procedure. Additionally, it is the responsibility of the Tech(s) to assure that any measuring device has been calibrated, or, if not, that a secondary calibration has been performed on it prior to making measurements. See the section on Calibration for details.

2.1.4 Test Documentor

When appropriate to the experiment being performed, one person serves as the Test Documentor (TD) with responsibilities to take digital photographs of the experimental setup and of significant events during the performance of the experiment. Additionally when possible a webcam recording should be made to document any visual results that can be captured in the field of view of a simple webcam attached to a lap top computer. A 30 second video file should be sufficient record experiment results.

2.2 Laboratory Equipment

All equipment and instrumentation shall be handled carefully to avoid damage during experimental operations. At no time shall any equipment be relocated from its position in the Lab.

Operating instructions shall be strictly followed.

2.2.1 Equipment Malfunction

Any anomalies encountered with equipment during an experiment shall be brought to the instructor's attention immediately. The procedure shall be stopped until the problem is resolved and the instructor gives approval to continue. In some cases it may be necessary to start the Lab from the beginning rather than continuing from the point of interruption.

2.2.2 Equipment Repairs

No repairs or attempted repairs shall be performed on any lab equipment, including instrumentation, fixtures, and especially pressurized systems or components.

2.2.3 Equipment Substitutions

Only the equipment specified in the Equipment List for each procedure shall be used. Equipment substitutions are prohibited without prior instructor approval.

2.3 Operations Precautions

Opening and Closing of Valves : Unless otherwise noted in a procedure, valves shall be opened and closed slowly to prevent shock (water hammer) in the system.

See individual experiment documentation for relevant precautions.

2.4 Procedures & Sequence of Operation

When given in test procedures, the sequence of steps specified in each procedure is mandatory. **No steps shall be performed out of sequence.** All Prerequisites and Preparations shall be completed as specified before commencing with the Detailed Operations of the procedure.

2.5 Lab Cleanliness, Post Experiment Clean-Up

Operational areas shall be maintained clean and orderly, free of trash or combustible materials. Food and beverage are not permitted in the Lab. Smoking is prohibited.

At the completion of each experiment, the team shall account for all equipment and instrumentation that was used during the procedure ("sponge count"). Equipment taken from storage racks or cabinets shall be returned to designated storage locations. The area where the lab was conducted shall be cleaned, and returned to the condition found when entering the lab to begin the procedure.

In the event that there is insufficient time at the end of a lab period to accomplish the above clean-up and equipment return, the TC shall delegate this responsibility to one or more team members as a follow up activity to be accomplished within 2 days.

3 Laboratory Safety

All safety requirements as specified in this section will be strictly enforced.

3.1 General Preparation

Each procedure contains specific steps in the Prerequisites, Preparations, and Detailed Operations sections that control the experiment to (1) ensure good data is obtained and the experiment is completed successfully, and to (2) ensure the experiment is conducted safely. **It is imperative that each team member thoroughly read the entire procedure before coming to the lab.** Each team member shall have reviewed the procedure in its entirety prior to beginning the lab, and shall understand the objectives, operations, and hazards that may be encountered during the experiment.

3.2 Unsafe Conditions

Should an unsafe condition develop during the experiment, the Test Conductor shall immediately initiate the required action to prevent injury to team members or damage to lab equipment.

Upon observing a hazardous or potentially hazardous condition that could occur if uninterrupted operation is allowed, **ANYONE** participating in or observing the experiment can issue a “STOP” command. The “STOP” command must be obeyed by all team members and observers involved in the experiment. The operations may only be resumed after the condition has been corrected or the team determines the hazard has been abated, with instructor approval.

3.3 Safety Equipment

Where safety clothing or safety equipment is required, the procedures shall not start until the equipment is in the immediate vicinity of the experiment and is ready for use. Examples of safety equipment include safety glasses, protective gloves, or protective smocks. The procedures will specify the applicable safety equipment required to conduct the experiment.

During Detailed Operations, team members have responsibility for assuring that they are equipped with adequate hearing and eye protection if so specified in the procedure.

3.4 Clothing

In most cases, typical attire worn to class is acceptable in the lab. However, **bare feet, high-heel fashion shoes (e.g., spike heels), open-toe shoes and sandals are not permitted.**

When working around reciprocating equipment or rotating machinery, avoid loose fitting clothing and jewelry (especially chains or necklaces) that could get caught in moving or rotating mechanisms. *Very serious injuries can result.* Precautions should be taken with long-sleeve shirts, and neckties (although seldom worn by students these days!) should be removed.

3.5 Electrical Safety Requirements

3.5.1 Electrical Connections

Electrical connections shall not be made or broken while energized or during Detailed Operations, unless otherwise specified in the procedure.

All electrical connections, including cords and plugs, shall be inspected for damage, corrosion, or foreign materials that could present a safety hazard, prior to mating.

3.5.2 Wires and Cables

Wires and cables shall be routed to avoid wear or damage resulting from exposure to undesirable conditions (e.g., abrasion, foot traffic, excessive temperature).

3.5.3 Leakage or Spillage of Water

In the event of leakage or spillage of water, electrical power to the experiment shall be killed. Prior to the start of operations, team members shall identify and be familiar with the location of circuit breakers or power cut-off switches to electrical equipment in the test area.

3.6 Notes, Cautions and Warnings in Procedures

Within the Detailed Operations section of the procedure, some steps will be preceded by **NOTE**, **CAUTION**, or **WARNING** paragraphs. *These always precede the step for which they apply.* A **WARNING** alerts the Test Conductor and the team that the operation, if not followed in accordance with the procedure, could result in personal injury. A **CAUTION** warns against conditions or operations that if not properly performed have the potential to damage lab equipment or the facility. A **NOTE** highlights information or provides a clarification for the step that follows.

4 Lab Reports

Each student will be responsible for preparing a report after completing each laboratory exercise. The required content and format of the report are given in the following sections.

4.1 Report Content

All written reports shall contain the following:

- A statement of the ***objectives*** of the exercise.
- A description of the ***test method*** that was used.
- A brief description of the ***test procedure***.
- A summary of the ***test results***.
- A summary of the ***conclusions.***
- Appendixes containing:
  - A ***copy of the as-run test procedure***, including an ***equipment list*** and the ***raw data*** recorded during the experiment.
  - ***Sample calculations*** (as applicable) to support the results and conclusions.
  - ***Digital photographs*** that photo-document important steps in the completion of the experiment.
  - ***Reference to a video file*** which documents the critical measurements that pertain to the stated goals of the experiment.
  - Descriptions of any ***secondary calibrations*** made to measurement devices.

4.1.1 Objectives

The objective or objectives of the experiment should be stated at the beginning of the report. One or two sentences are usually sufficient to summarize the purpose of the experiment. It is not necessary to include a discussion of basic theory relevant to the experiment.

4.1.2 Test Method

This is a brief description of the experimental approach used to satisfy the objectives. It is written in past tense, because it describes experimental work that was completed. This section should include a brief description of the test apparatus and instrumentation that was used. Where appropriate, a schematic diagram should be included that identifies the major components of the test system (valves, flow meters, pressure gages, etc.). If commercially available equipment is used (e.g., viscometer), a brief description of the equipment, including manufacturer and model number, should be provided. Refer the reader to the appendix for the detailed equipment list, which will be part of the as-run procedure.

4.1.3 Test Procedure

A description of the procedure that was used to obtain the test results shall be provided. *Summarize* the detailed steps that were used; do not repeat the detailed steps in this section. Refer the reader to the appendix for step-by-step details contained in the as-run procedure.

If no formal test procedure was included in the provided experiment documentation then an outline of the test procedure which was actually followed should be submitted in the lab report.

4.1.4 Test Results

Test results obtained from the experiment shall be provided in the applicable format:

- Narrative
- Tabular
- Graphical
- Digital photographs and/or digital video
- A combination of the above.

This section should present the reduced data, not the raw experimental data. For example, if the objective of the experiment is to determine the viscosity of a fluid as a function of temperature, then that is the data presented. In this case, a graph showing viscosity versus temperature is the recommended format for presenting the experimental results. The determination of viscosity may have required a number of measurements (raw data), which were used to calculate the viscosity at different temperatures (reduced data). Recommended formats for tables and graphs are provided in section 4.3 of this manual.

This section should also include a brief description of how the reduced data was obtained. Identify formulas, charts, tables, or handbooks that were used to obtain the final results. Refer the reader to the appendix for sample calculations illustrating the use of formulas, charts or handbook data in obtaining the results.

4.1.5 Conclusions

This section summarizes your conclusion regarding the results. If the results differ from those expected, provide an explanation based on an analysis of the data. Examine any assumptions that were used that could be adversely affecting the results. Consider experimental error as a cause of the differences. The conclusions should be based on (1) the experimental results, and (2) supporting technical rationale and analysis.

4.2 Report Format

The report shall be typed using word processing software. Text shall be double-spaced, using 12-point font. Equations may be handwritten, but if available, it is recommended that an equation editor be used instead.

4.2.1 Cover Page

The report shall have a cover page with the following information provided:

- Number and title of experiment.

- Course title such as MET/CET 3180 Fluid Mechanics I
- Date of submittal
- Student's name

4.2.2 Recommended Outline

It is recommended that the report be broken into sections as follows:

1. Objectives
2. Test Method
3. Test Procedure
4. Test Results
5. Conclusions
6. Appendixes

4.3 Presentation of Data

Experimental results should be presented in a clear and concise manner. In some cases, a tabular presentation is appropriate. Use the table function in the word processor to format the rows and columns. Provide labels for the columns, indicating the units for the numerical data provided. Set spacing so that the table is easy to read, and align the numbers in the columns for improved readability.

4.3.1 Use Microsoft Excel or McGraw Hill EES

It is strongly recommended that spreadsheet software, such as Microsoft Excel, be used to develop graphical presentations of data. (In courses that offer McGraw-Hills EES software student version, screen copies of solutions and plots are equally acceptable to Microsoft Excel presentations.) The independent and dependent variables can be entered into the spreadsheet, and the graphing function can be used to create an X-Y plot of the data. Be sure to label axes, and provide legends if multiple plots are presented on a single graph. When presenting graphical data, remember that any points specifically shown on the graph should be test results or test data only. If the plot is developed from a formula, present the results with a line plot.

4.3.2 Common Mistakes to Avoid

Here are a few common mistakes that should be avoided in your presentation:

- Tables split between pages without repeating table headers. You should make sure tables are contained on one page; otherwise, configure the table to place a complete header on each section of the table.
- Plots without: titles, specific data legions, or axis labels without units or improper units.

- Equations not centered by themselves on a page line, without equation numbers and without identifying all terms used in the equation along with their units.
- Pages without identification or page numbers. Use headers or footers to identify each page along with page # of #.

5 Lab Exercises

Course specific, individual experiment documentation will be provided by your instructor for all experiments that are to be performed during the semester. These experiment writeups will be distributed at the beginning of the semester or, in some cases, within a week before the experiment is to be conducted. They should be included in this manual separated by dividers. It is intended that you will keep all papers associated with each experiment together under the same divider.