

# INTRODUCTION

The main focus of this report is to provide resources and ideas for changing the current structure and coursework of BSE 2105/2106 – sophomore laboratory. In general, this report follows the conception that the new structure of this course requires sophomores to complete several small (2-4 weeks) design projects during the course of the fall semester. The sophomores will also be vertically integrated, in some capacity, with the senior design course. For reasons discussed in the *explore possibility of vertical integration* section, this vertical integration will also take place during the fall semester.

A lot of work has been done to identify suitable small design projects for sophomore level students. A full description of these possible design projects is located in *possible design projects*.

While identifying these design projects it was found that certain equipment and instruments are required to conduct certain design projects. Some of these instruments had not been used for several years and the last people to use them, the “experts”, were no longer available. Not only were repairs necessary but also was locating the instructions for the instruments and if this was not possible adequate instructions needed to be written from scratch.

Work was done to get this equipment, specifically the Brookfield viscometer, Haake viscometer and the 21X dataloggers, up and running. Repairs were made to the instruments and since suitable instructions for the instruments could not be located, proper instructions for all instruments were written from scratch. Hopefully, this will eliminate any future problems with this equipment and allow future classes to easily operate the instruments without the help of an expert. Instructions for use of these instruments are located in the sections labeled *instructions for 21X datalogger* and *instructions for viscometers*.

# POSSIBLE DESIGN PROJECTS

## 1. FLOW OF GRANULAR SOLIDS

### 1.1 *Problem description*

Design a bin that allows a specific amount of a granular material to flow from a bin in a specific amount of time. Each design team works with a different granular material either sugar, coffee, or non-dairy creamer. The designed bin should allow 250 grams of this granular material to flow from the bin in exactly 30 seconds.

At the end of the design project each design team is given three opportunities to test their bin. An average of the three flow times is taken and a portion of the design team's grade is based on how close this time is to specified time (30 seconds). Times are always rounded down (1.99 seconds is rounded down to 1 second). Grades on this portion of the design are as follows:

|                           |   |
|---------------------------|---|
| 30 plus/minus 1 second:   | A |
| 30 plus/minus 2 seconds:  | B |
| 30 plus/minus 5 seconds:  | C |
| 30 plus/minus 10 seconds: | D |

The bin is designed to create funnel or mass flow depending on what is desired by the instructor. The material used to build the bin should be transparent so that the type of flow may be observed. Preliminary testing has shown that Plexiglas is the best building material. The instructor requires all design teams to design a bin for funnel flow; depending on success of the funnel flow design, the instructor may then order teams to design a bin that produces mass flow.

Another option is to require some design teams to design a bin that produces mass flow and the others to design a bin that produces funnel flow. The third and final option is to require each group to design a bin that produces mass flow and another that produces funnel flow.

A final option is to require the bin to be in an hour glass form with the flow of the material mass flow in one direction and funnel flow in the other direction. This is the most difficult design because an hour glass design has the same size orifice for both directions (types) of flow and the size of the orifice that satisfies above time constraints will not be the same for both types of flow.

### 1.2 *Resources*

The type of flow, flow rate, etc. depend on several factors that are described in literature. Most of these are property values. The property values the students will need, from flow standpoint, are 1) cohesion and 2) angle of internal friction; however, if the particle sizes are relatively large (for example, table sugar), then cohesion is nearly zero. In this case students may substitute angle of internal friction with angle of repose (or emptying angle).

For flow rate estimation, students will need the parameter values specific to the equation. The flow equations, generally, apply to only large size particles. Friction will be useful for designing a non-bridging opening for cohesive materials.

There is no single source that lists the property values, which are distributed throughout the literature. Locating property values could be part of the student's assignment. If students cannot find values (or values just do not exist), then testing is essential. In industry, formulations are changed routinely. Therefore, published values will not, and do not, work. From this exercise an important lesson will be learned by students, i.e., testing is an integral part of the design process.

### 1.3 *Materials*

The instructor can provide each design team with all materials. This includes building material, glue, tape, etc. and the granular material. The instructor randomly assigns each design team one of the above-mentioned granular material.

A second option is to have the design teams themselves buy the materials. The instructor gives each design teams a budget of around \$20, which cannot be exceeded. The design team purchases all materials with this \$20. This option has advantages in that it adds an economic twist to the design and forces students to conserve supplies. Teams must keep receipts on all purchases and are penalized for exceeding the \$20 budget. If a design team uses less than \$10 they are rewarded with extra bonus points.

## 2. **MIXING**

### 2.1 *Problem description*

Solid-solid mixing:

Design a mixer that mixes three different types of dried beans. Each design team is given 150 grams of each type of bean. The design team mixes the beans in a mixer they design and build. The types of beans available are listed in Table 1.

Table 1

| Type                   | Color     | Average weight of one Bean (g) |
|------------------------|-----------|--------------------------------|
| Small Lima Beans       | off-white | 0.049                          |
| Green Split Peas       | green     | 0.078                          |
| Field Peas             | tan       | 0.095                          |
| Black Turtle Peas      | black     | 0.200                          |
| Small Red Beans        | red       | 0.325                          |
| Light Red Kidney Beans | light red | 0.517                          |
| Large Lima Beans       | white     | 1.246                          |

The mixer should be able to mix different combinations of types of beans. The instructor may have students mix three, four, or even all seven types of beans. Which types of beans and how many different types of beans are mixed is a decision left for the instructor. After mixing, a sample of the bean mixture is taken in order to evaluate

effectiveness of mixing process. Students divide the mixture in half until they have an amount that can be separated in a reasonable amount of time. If there is an equal weight within the sample mixture of each type of bean then the mixing process is classified as successful.

Obviously any mixer can provide a successful mixture if the mixing process has no time constraint; therefore, design teams are required to find the minimal amount of time the mixer must run in order to produce a successful mixture. The design team not only finds this optimal time but also attempts to design a mixer that generates the shortest possible optimal time.

#### Solid-liquid mixing:

Design a mixer that mixes soil, sand or rice and a colored liquid. The soil is sprayed with a specific amount of food coloring or dye and then mixed. The mixture is divided as before until there is a reasonable amount. The sample is washed with a specific amount of water, which removes the dye from the soil. A spectrometer is used to determine the amount of dye within the wash water.

Students must first calibrate the spectrometer by taking readings of water with known percentages of dye. Students generate a calibration curve with these data. The amount of dye within the sample can now be determined. This information allows students to evaluate effectiveness of mixing process by comparing ratio of total mass of dye and total mass of soil to mass of dye in sample and mass of sample. The closer the ratio the better the mixing. As before students must also find the optimal time of mixing.

Instructor can have some design teams design and build a solid-solid mixer and the other design teams design and build a solid-liquid mixer. Another option is to have all design teams design and build a solid-solid mixer and upon completion have the teams use the same mixer for solid-liquid. A final option is to have each design team design and build a solid-solid mixer and then design and build liquid-solid mixer.

## 2.2 *Resources*

No specific resources are needed for this design project. Students brainstorm about type of mixer they will design. Eventually the instructor will provide students with two designs of simple mixers. Design teams may decide to use one of these designs or the design they came up with during the brainstorming process. The instructor provides information on spectrometer and particle size.

## 2.3 *Materials*

Mixer will be made from simple inexpensive building materials. This point is made clear before the students begin to brainstorm. The point is emphasized when the students are presented the simple mixers since one is made out of cardboard and the other from two liter plastic bottles. Instructor provides the beans, the sand, soil or rice and the dye. A spectrometer must be available for evaluation of solid-liquid mixing.

### 3. MASS AND ENERGY BALANCE

#### 3.1 *Problem description*

A simple apparatus is built for the students that combines two streams of flowing water into a single stream. The two entering streams are maintained at constant but different temperatures. A valve controls the flow of the entering streams so that the flow can be varied.

The apparatus consists of two large coffeepots, two Rotameters, copper tubing and joints. The two large coffeepots are filled with water. The water in one of the coffeepots is kept at room temperature while the water in the other is heated to a specific temperature. Students vary the entering flow rates so that the water exiting the bin is a specific temperature. The instructor chooses this exiting temperature and requires students to find entering flow rates for several different exit temperatures.

The flow rate and temperature of water at all three locations must be measured. Students are introduced to temperature measurement and use a thermocouple to measure temperature. Exit flow rate can easily be measured by using a stopwatch and beaker.

Exit flow rate can be measured more precisely than using stopwatch and a beaker. The method is described below and is much more involved; however, it has its advantages because it is almost its own design project and also exposes students to instrumentation.

Students place an empty container and a weight of known mass on a triple beam scale. The scale is balanced to a reference point. The flowing water of exit stream is allowed to flow into an empty container. The scale's pointer will move above reference point, which triggers a timer to start. The weight is removed and the pointer falls below reference point, which should not trigger the timer. As the water in the beaker fills the pointer will rise. When the pointer reaches the reference point a third time the timer is triggered to stop. The amount of water that flowed during this time is equal to the mass of the weight; thus, the flow rate can be calculated. Equipment used to trigger the timer must be designed in a way that the timer is triggered on first and third passes and not the second pass. A pen light and photo-sensor could be used to accomplish triggering of timer.

#### 3.2 *Resources*

Instructor provides introduction and relevant information on mass and energy balance as well as flow rate and measuring flow rate. A specific resource is probably unnecessary. Students are also taught difference between volumetric and mass flow rate.

#### 3.3 *Materials*

Apparatus is provided for the students. As previously mentioned, materials used to build apparatus include two 42 cup coffeepots, two Rotameters (flowmeters), copper tubing and fittings. The Rotameter connected to one coffeepot (coffeepot 1) measures 100-1500 ccm of water while the rheometer connected to the other (coffeepot 2) measures 200-3000 ccm of water. The exit temperature required by the instructor may be closer to room temperature, closer to the temperature of heated water or in-between. If the exit temperature is closer to room temperature then coffeepot 2 should be kept at room temperature, if exit temperature is closer to heated temperature then coffeepot 2 should be kept at heated temperature, if the exit temperature is in-between then it does not matter. A

triple beam scale, beakers, weights, photo-sensors, timer, etc. are provided for measuring flow rate.

## 4. GRAVITY FLOW OF WATER THROUGH AN ORIFICE

### 4.1 *Problem description*

A gravity flow container is built for the students. An airtight cap that has a copper tube (vent tube) extending to the bottom of the container covers the top of the container. This cap allows the water to flow from the exit orifice of copper tubing, located 10-12 inches below bottom of container, at a constant rate. If the container has no cap (open vent) the flow rate will decrease as the level of water in the container decreases.

This concept is presented to the students as a demonstration or can be proven by the students by having them collect their own data. The flow rate will depend only on the diameter of the exit orifice, the length of the vent tube and the length of exit copper tubing. Much to the surprise of the students the diameter of the vent tube does not effect flow rate.

If the vent tube diameter is too large ( $\approx 5$  or more times greater than exit diameter) the flow rate is not constant and the instructor explains the reasons for this. Combinations of vent tube diameter and exit diameter that do produce constant flow rate and data collects for them are listed in Table 2. As previously mentioned the apparatus has copper tubing extending 10-12 inches from the bottom of the container. Two containers are built one with inside diameter of extending copper tubing  $\frac{1}{2}$ -inch and the other with the inside diameter  $\frac{3}{8}$ -inch. This distinction is labeled as apparatus type in the table.

Table 2

| Orifice Diameter (inches) | Vent Diameter (Inches) | Apparatus Type | Average Flow Rate (g/s) |
|---------------------------|------------------------|----------------|-------------------------|
| 0.25                      | 0.125                  | 1/2            | 62.6                    |
| 0.25                      | 0.375                  | 1/2            | 62.7                    |
| 0.1285                    | 0.125                  | 1/2            | 20.5                    |
| 0.1285                    | 0.375                  | 1/2            | 20.6                    |
| 0.25                      | 0.125                  | 3/8            | 69.3                    |
| 0.25                      | 0.375                  | 3/8            | 69.6                    |
| 0.25                      | 0.500                  | 3/8            | 70.2                    |
| 0.1285                    | 0.125                  | 3/8            | 19.1                    |
| 0.1285                    | 0.375                  | 3/8            | 19.2                    |

The bottom of the extending copper tubing of each apparatus is fitted with a cap. The orifice diameter is the diameter of the hole drilled into this cap. Summary of data collected is listed in Table 3 and a complete list of data collected is located in the appendix.

Table 3

| Apparatus Type | Orifice Diameter (inches) | Average Flow Rate (g/s) |
|----------------|---------------------------|-------------------------|
| 1/2            | No Cap                    | 153.6                   |
| 1/2            | 0.25                      | 62.7                    |
| 1/2            | 0.1285                    | 20.5                    |
| 1/2            | 0.0625                    | 5.1                     |
| 3/8            | No Cap                    | 114.0                   |
| 3/8            | 0.375                     | 109.9                   |
| 3/8            | 0.25                      | 69.8                    |
| 3/8            | 0.1285                    | 19.1                    |
| 3/8            | 0.0625                    | 4.6                     |

#### 4.2 Resources

Students are required to design an orifice diameter for a specified flow rate. The instructor provides equations needed to calculate flow rate, which are listed below. A list of values for the constant C, which depends on type of orifice, is also provided. Calculations were conducted with data acquired and are listed in the appendix.

Q = flow rate

C = constant

A = area of orifice

V = velocity

g = acceleration of gravity

h = distance from exit to bottom of vent tube

$$Q = CAV$$

$$v = \sqrt{2gh}$$

#### 4.3 Materials

Apparatus is provided for the students. Apparatus consists of copper tubing and fittings, a valve, plastic container, cap and plumbers glue. Students are provided with a cap into which they drill the orifice.

### 6.3 *Materials*

Aluminum cans, wire and some starch or other substance that can be mixed with water to form a more viscous liquid. Viscometer is used to measure viscosity.

## EXPLORE POSSIBILITY OF VERTICAL INTEGRATION

Several options have been discussed in this area. The most promising scenarios involve integration of BSE Sophomore Laboratory class with senior design class. Currently, seniors in BSE work on a yearlong design project. The project identified and defined during the fall semester and then building, testing, and writing of final design report is conducted during the spring semester.

The BSE Sophomore Laboratory class is also a year-long course. During the spring of 1999 sophomores in this class were given the option of working with a senior design team as a sort of apprentice. The sophomores who accepted this opportunity were given 1-credit hour. Results of this experiment were mixed. Most of the sophomores and seniors agreed it would be much more useful for the sophomores to work with the seniors during the fall semester when the research and planning is conducted.

The department plans to have sophomores work with seniors during the fall 1999. It may be a required part of the sophomore course or offered as before, a separate 1-credit hour course. This decision will be left to the instructor of the sophomore course.

- Scenario #1: sophomore-senior interaction; 3-year design project.

*Sophomores* work with the seniors on their 3-year design project. This would occur during the fall semester. Sophomores would work as an apprentice for the senior group. During the spring semester the seniors would help the sophomores identify their own 3-year design project.

*Junior* involvement in this scenario is limited. The junior does very little work on the 3-year design project during this year. Juniors take courses more specific to their field and this new knowledge should prepare the students with the necessary knowledge to handle a year-long design project.

*Seniors* would immediately begin work on their 3-year design project during fall semester. Seniors utilize help of sophomores. During spring semester seniors wrap up project as well as help sophomores identify his/her own 3-year project.

### Concerns/questions

- Is it realistic to have a student work on the same design project for three years?
- Would this require groups to be formed during the sophomore year?
- What about working with different people, different groups?
- How tied into the selected design project should the student be, that is, should a senior have the freedom to change design projects at beginning of fall semester?
- Is it realistic to put a design project on hold for a year?

### On the plus side

- Introduction to design early in college career.
- Identifying design project in field of interest during sophomore year requires sophomores to closely examine their choice of field.
- Does not require addition of new courses.
- Scenario #2: sophomore-senior interaction; junior-senior interaction; addition of a junior design course; 1-year senior design project.

*Sophomores* work in spring semester with seniors assisting them with their senior design projects.

*Juniors* take a new junior design course. The course is offered in the fall. In this course the student would complete several small design projects. The students would work in a group; however, the groups would change for each project. At the end of the course the juniors would identify a senior design project with the help of the seniors.

*Seniors* immediately begin work on senior design project identified the previous fall. Seniors help juniors identify their own design project at the end of the fall semester. Seniors finish the design project in the spring with the help of the sophomores.

### Concerns/questions

- Requires addition of a new course.
- Can we find appropriate small design projects for the juniors?
- Should we limit juniors to working on small design projects within their area of interest or should we simply assign the design projects to teams at random?

### On the plus side

- Introduction to design early in college career.
- Interaction occurs at all levels.
- With several small design projects juniors get a feel for type of design project he/she may enjoy before choosing a senior design project?
- Work with different groups.
- Scenario #3: sophomore-senior interaction; addition of a junior design course; 1-semester senior design project; very similar to scenario #2.

*Sophomores* work with seniors on their senior design projects during the spring semester.

*Juniors* take a new junior design course in the spring semester. The course is identical to that of scenario #2 with the exception that the juniors will work on their own to identify a

senior design project. This course would replace the existing fall semester senior design course.

*Seniors* start their design project identified the previous spring. The project is completed in one semester with the help of the sophomores.

#### Concerns/questions

- Requires addition of new course.
- Can we find appropriate small design projects for the juniors?
- Should we limit juniors to working on small design project within there area of interest or should we simply assign the design projects to teams at random?
- Senior design project is identified and then put on hold for a semester. Is this OK?

#### On the plus side

- Introduction to design early in college career.
- Addition of new course is balanced by elimination of fall senior design course.
- With several small design project juniors get a feel for type of design project he/she may enjoy before choosing a senior design project?
- Work with different groups.

Obviously additional scenarios are possible as well as combining of aspects of existing scenarios.

# INSTRUCTIONS FOR USE OF 21X DATALOGGER

## PC200W and Shortcut for use with the 21X Datalogger

These are directions for connecting the 21X Micrologger to a computer for uploading programs and downloading data using the PC200W software provided by Campbell Scientific.

|  |     |
|--|-----|
| Table of Contents  | pg. |
| Installation of PC200W and Shortcut Software                   | 16  |
| Starting PC200W software for communicating with the Datalogger | 16  |
| Programming using the Shortcut Editor                          | 17  |
| Programming the Thermocouple                                   | 17  |
| Programming the LI-200SA Pyrometer                             | 18  |
| Setting up Data Recording Intervals                            | 18  |
| Saving Your Program and Wiring the Sensors to the Datalogger   | 19  |
| Sending Programs to the Datalogger                             | 20  |
| Downloading Data from the Datalogger                           | 20  |

## Installation of PC200W and Shortcut Software

1. Put PC200W disk into the floppy drive.
2. Click on Start menu and choose Run.
3. Type *a:\setup.exe* and click OK
4. Setup program will provide directions from there.
5. Remove PC200W disk from drive.
6. Put Shortcut disk into floppy drive.
7. Again go to the Start menu and choose Run.
8. This time, type *a:\install.exe* and follow the instructions given by the Shortcut installer.
9. Once this is finished you should have successfully installed the two software programs. Proceed to **Starting the PC200W software**.

### Starting PC200W software for communicating with the Datalogger

1. Connect serial cable to datalogger and to the computer.
2. Start up PC200W software by going to the Start menu, then Programs, then PC200W, then click on PC200W.
3. Turn on Datalogger (if it isn't on already).
4. Wait for Datalogger to stop displaying HELLO if it is doing so
5. If the 21X Datalogger is not shown graphically in the white space at the bottom left of the screen, you will need to click on "Add Logger". When you do this, a list will be displayed. Choose the 21X from that list and click OK.
6. Click on the "Connect" button shown in PC200W.
7. Wait for the button to change to "Disconnect", meaning communication with the data logger has been established.
8. Check to see if the time and date need setting on the datalogger by looking at the section labeled "Logger Clock" which is in the middle of the screen on the right hand side. If you would like to set the clock to the time and date of the PC you are working with, simply click on the button in the logger clock section that says "Set Now". The display in the "Logger Clock" section will automatically be set.
9. If you wish to make a program from the 21X Datalogger then see the **Programming** section.
10. If you wish to send a program you already have to the 21X Datalogger then see the **Sending Programs to the Datalogger** section.
11. If you wish to collect the data that the logger has collected then see the section labeled **Downloading Data from the Datalogger**.

## **Programming Using the Shortcut Editor**

1. To program the datalogger, click on the button labeled “New/Edit” located in the Programming section that is on the lower right hand side of the screen. This will start the Shortcut Editor.
2. When the Shortcut program first opens, you will see a screen that displays four smaller windows, each with a heading of Step 1, Step 2, Step 3, or Step 4.
3. The first step involved opening a datalogger program. Creating a new file or modifying an existing file can do this.
4. To create a new file, click on the “New Program” button that is in the step one window. If you wish to edit an existing file, click on the “Existing File” button in the step one window.
5. You will then be given the option to name the file. Type in the name of the file you wish to create if it is a new file, or type in the name of the existing file if you wish to edit a file, and then press enter. Omit the file extension when entering the name as Shortcut will append the correct extension.
6. Once you have chosen a file name, Shortcut will ask you what kind of datalogger that you have. Select 21X then click on OK.
7. Now, the Step 2 window should be highlighted. Select the option “Go to Window”.
8. The first option that appears during this step is the scan rate, which is the amount of time, in seconds, that the datalogger waits between taking readings. Type in the number of seconds that you wish it to wait and then click OK or press Enter.
9. Next, what you will need to do is add the appropriate sensors. Within these instructions are specific references for various sensors. Find the section related to the specific sensor you are intending to use and follow the directions there to finish programming.

## **PROGRAMMING THE THERMOCOUPLE**

1. Select Meteorological from the sensor types menu at the top left of the screen.
2. Under the meteorological sensor group, select the reference temperature !21RFTMP.M by clicking on it.
3. Once the choice is highlighted, click on the “Add” button or press Enter.
4. A new screen opens. Click on “Add” to finish adding the reference temperature to the program for use with the Thermocouple sensor.
5. Now you should add the Thermocouple sensor, which is listed as TC\_DIFF.M To do this find the listing for it and click “Add” or press Enter.
6. A new window opens which lists more detailed information about the sensor. There are onscreen instructions about how to adjust temperature measurements from Celsius readings, which is the default, to Fahrenheit.
7. Click on the “Ref Temp C” button, near the bottom right, and select the reference temperature sensor, !21RFTMP.M, in the window that appears. Once the reference temperature sensor is selected, click OK.
8. Now select the Thermocouple type that you are using from the available choices. Available types are Type T (copper/aluminum), Type E (Chromel/Constantan), Type K (Chromel/Alumel), and Type J (Iron/Constantan) thermocouples.
9. Click the “Add” button to finish adding the thermocouple sensor.
10. Now you may add any other sensors you wish by looking at their respective sections within this documentation. If you have no other sensors to add proceed back to the main

documentation for doing programs in shortcut and follow the directions related to **Setting Up Data Recording Intervals**.

## PROGRAMMING THE LI-200SA PYROMETER

1. Select the Custom Group from the Sensor Types menu at the upper left-hand side of the screen.
2. Click on the Available sensor section and go through it until you find the MILVOLTS.O sensor. Click Add or press Enter.
3. In the new window that opens, there is a listing for a multiplier. To find the multiplier for the pyrometer you are using:
  - Find the multiplier tag on the pyrometer cable.
  - Take the absolute value of the multiplier.
  - Divide that number by the resistance listed on the BNC adapter (147 ohms).
  - Multiply the number you come up with by 1000.
  - This number is your multiplier.
4. Leave the offset at 0.
5. Click on the "Add" button.
6. Now you may add any other sensors you wish by looking at their respective sections within this documentation. If you have no other sensors to add proceed to **Setting Up Data Recording Intervals**.

## Setting Up Data Recording Intervals

1. Click close to leave Step 2 of the editing process in Shortcut.
2. Next, open the Step 3 window.
3. In this screen there are three windows on the right hand side labeled 1, 2, and 3 respectively.
4. Each of these windows has a section in brackets with a number in it with the word "minutes" to the right of the brackets. This is the amount of minutes that will pass in between each reading you have the datalogger take.
5. The three windows have preset readings that they will output to the data file. The first preset is the array number. The array number corresponds to the window number you have selected (i.e. Window 1=Array 111, Window 2=Array 222, Window 3=Array 333). The second preset corresponds to the current year, the third to the current Julian date, and the fourth to the current time.
6. Each window can report data from whatever sensors you choose, the order in which the data is shown is based on where the reading is shown in the window.
7. To read data from a specific sensor, select the appropriate sensor from the window on the left by clicking on it. The description for the selected sensor is given in a small window at the bottom on the left side.
8. The type of measurements that can be taken is shown in the middle of the screen. Select the desired measurement type.
9. To remove a measurement from one of the windows on the right, click on the measurement and click the Delete button.
10. To disable one of the three windows simply click where you would enter the number of minutes between readings and set it to 0.

11. Once you have added all the readings you would like to take click Close and the program will return to the menu you saw when the program started. however this time step four will be highlighted.

### **Saving Your Program and Writing the Sensors to the Datalogger**

1. You should now be at the Step 4 window.
2. Click on "Go To Window" or press Enter.
3. At this point, Shortcut will tell you that it has saved the program file which will eventually be sent to the datalogger.
4. Click OK.
5. A menu will appear on the right hand side of the screen. Choose the "Analog Channels" by clicking on it. This will show how the datalogger will expect the sensors to be wired to their respective channels.
6. Each channel is listed as the channel number followed by either an H or an L. These are the same as the H and L labels on the channels located on the datalogger itself.
7. Specific wiring information for the sensors that have a programming section listed in this documentation are as follows (note, this listing is what is shown in the window on the left after Analog Connections have been selected. These are the wires that the listing correspond to.):
  - Thermocouple:
    - Type T Thermocouple – Copper wire – T/C Not Red
    - Constantine colored wire – T/C Red
  - LI -200SA Pyrometer
    - Green wire – mV Signal +
    - Blue wire – mV Signal –
8. After you have finished wiring the datalogger click "Exit" on the menu bar that is across the top of the screen. This will take you back to PC200W. You are now ready to upload the program to the datalogger.
9. Proceed to the **Sending Programs to the Datalogger** section.

## **Sending Programs to the Datalogger**

1. To send a program to the datalogger, click on the little folder next to the white text box under the Associated Program section of the window, located at the bottom right corner of the screen.
2. This will open up a window that will allow you to browse for a file. At this point you have to find and choose the program file you wish to upload. This file will have the extension *.dld*. If this is a file that you have just created with Shortcut it is probably in the *C:/shortcut* directory.
3. Once you have chosen the file, click on OK.
4. Once you have returned to the main PC200W screen, click on the Send button located at the bottom right of the screen in the Program window.
5. The program should show a bar indicating its progress, then tell you the program was downloaded successfully.

## **Downloading Data from the Datalogger**

1. Click on Data Collection from the top row of buttons in the PC200W program.
2. After this you should see a section labeled Collect To at the bottom left corner of the window. Click on the small folder at the end of the white text box that is located at the bottom left of the screen.
3. Type the file name you wish to save the data to and click OK.
4. Once this is done, click the button labeled Collect Now. This will use the connection with the datalogger to download the data it has collected so far. If no data is currently stored in the datalogger's memory, a window will appear telling you that there are no arrays to be collected.
5. Data obtained from the last step will be displayed in the large white box on the right side of the window. The data will be sets of numbers, but the exact meaning of the data shown will be as defined within the program the datalogger was running at the time you collected the data.
6. Once the data has been retrieved to the screen, it will also be stored to the file that was specified in the "Collect To" box earlier and removed from the datalogger's memory.

# INSTRUCTIONS FOR USE OF VISCOMETERS

## Viscosity Measurement

### Definition of terms:

*Viscosity* can be defined as resistance to flow. The higher the viscosity a fluid has, the more resistance it will offer when forced to flow. Therefore, more energy will be needed to pump the fluid. Fluids are classified according to their “behavior”. The two major categories are Newtonian and non-Newtonian. Whether a fluid is *Newtonian* or *non-Newtonian* is determined by examining the flow behavior curve (shear stress vs shear rate) of the fluid.

A Newtonian fluid is an ideal fluid in which the relationship between shear stress and shear rate is a straight line passing through the origin. The ratio of shearing stress to shearing rate in Newtonian fluids is called the *viscosity coefficient*. A non-Newtonian fluid is a liquid in which the relationship between shear stress and shear rate is not linear. If the flow curve is concave to the shear stress axis, the flow is called *dilatant*. If the flow curve is convex to the shear axis, the flow is called *pseudoplastic*. The *apparent viscosity* of a non-Newtonian is the viscosity of a Newtonian fluid exhibiting the same resistance to flow at the chosen shear stress or shear rate. It is determined by the slope of a straight line connecting the chosen point on the non-linear curve to the origin.

Some fluids display thickening or thinning characteristics at a constant shear rate. Those fluids that show a decrease in shear stress with time at a constant shear rate are called *thixotropic* fluids. Those fluids that show an increase in shear stress with time at a constant rate are called *rheopectic* fluids.

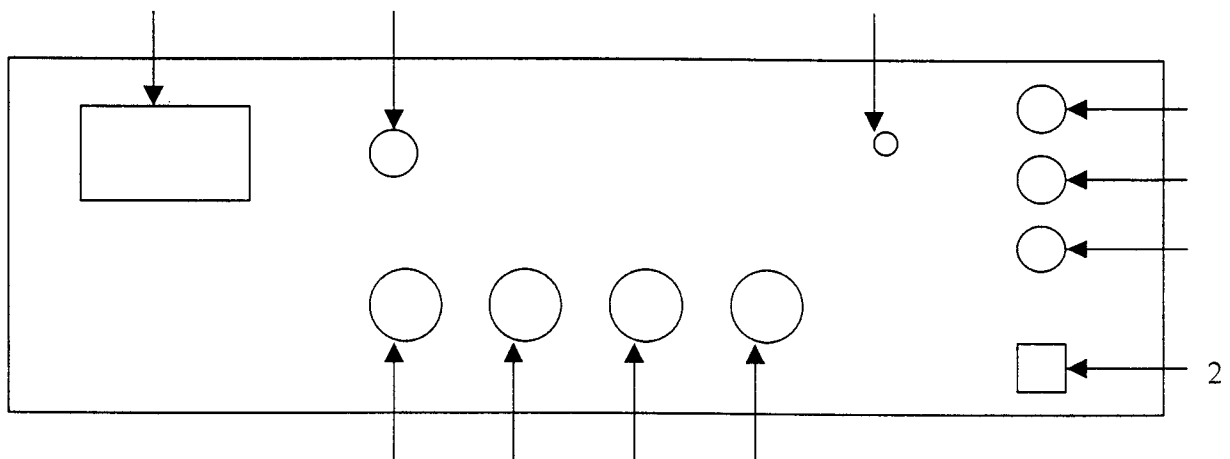
The characteristics associated with fluid behavior can be taken advantage of to design fluids that are tailored to a specific application. Fluids that will not support a “non-zero” value shear stress are called *viscous* and convert all of the energy used to move the fluid into heat. Fluids can exhibit solid-like behavior to a varying extent. Fluids such as these are called *viscoelastic* and store some of the energy used to move them. This energy is released when the fluid comes to rest.

### Measuring viscosity:

Devices called viscometers measure viscosity. Viscometers fall into two general categories: rotational and capillary or tube. Rotational viscometers possess a rotating spindle, which transmits fluid drag forces to a torque transducer. Torque and angular velocity are used to calculate viscosity. Tube viscometers are basically pipes or tubes through which fluid is forced by an externally applied pressure. Pressure and flow rate are used to calculate viscosity. These devices are designed so that they create what is called a *viscometric flow* in a fluid. A viscometric flow is one in which only one non-zero shear rate component exists in a typical three-dimensional coordinate system. This type of flow is the simplest and minimizes the complexity associated with viscosity calculations.

A schematic of the geometry of the “sensor” system (a cup and spindle) of one of the viscometers to be used in this laboratory is shown in Figure 1. The cup, in which fluid is placed, is typically elevated until the spindle is properly immersed in the fluid. Alternatively, the cup and spindle can be attached to the viscometer and the fluid added later to the appropriate level. The appropriate level depends on the design of the spindle. The surface of the spindle immersed in fluid experiences drag that results in a force being created at a distance equivalent to the radius of the spindle. The force acting through this distance creates the torque that is sensed by the viscometer. The forces created throughout the fluid and caused by the velocity gradient in the fluid influence the drag force that is sensed at the spindle surface.

Schematic of front panel controls of Haake viscometer:



- |   |  |
|---|--|
| (1) Pushbutton “stop”<br>Depressed pushbutton | The instrument is ready for operation, but the drive does not rotate yet.  |
| Released pushbutton                           | Drive rotates according to preset test speed.  |
| (2) Pushbutton “mains”                        | On/off power switch. The instrument is switched on when this pushbutton is depressed.  |
| (3) Digital counter                           | Measurement value “S” 0 to 100-scale grad. When the permissible torque is exceeded, the digital counter will blink. In case of overload change the measuring conditions (reduce speed or change system).                     |
| (4) Knob                                      | Fine setting of the zero point on the digital counter.   |
| (5) Knob                                      | Speeds ranging from rpm = 1 to rpm = 512.  |
| (6) Warning lamp                              | Blinks red when the permissible maximum speed has been exceeded – when external programmers are being used.  |
| (7) Knob “R”                                  | Reduction of speed set on (5):<br>1 – no reduction<br>2 – reduction 10:1<br>3 – reduction 100:1  |
| (8) Knob                                      | Changes torque range (3 positions):<br>1 :basic measuring range<br>0.33 :sensitivity increased by a factor of 3.03<br>max. :adjust 100% measuring range to basic unit (see section 6.0 of manual) and recorder (section 5.2) |
| (9) Pushbutton “D”                            | Damping can be set from 0 to 10.   |
| (10) Pushbutton “INT”                         | Pushbutton depressed: speed can be controlled.   |
| (11) Pushbutton “EXT”                         | Pushbutton depressed: external programmers take over speed control.  |

#### Operation of Haake viscometer:

1. Adjustment: see section 6.0 of instruction manual rotovisco RV12.
2. Connect basic unit to mains and depress main switch.
3. Set to medium test speed: e.g.  $n = 64 \text{ min}^{-1}$
4. Lightly hold shaft of the measuring drive unit with your hand (set  $E = 1$ ).
5. Depress pushbutton stop.
6. Adjust zero and maximum indicator of the measuring drive unit.
7. Fill the sensor with the substance to be tested. For best results when using MV MV II cylinder of I fill cup approximately 1/8” below etched line.
8. Start the circulator and wait for the temperature to stabilize.
9. Dial the desired speed (release pushbutton “STOP”) and read off or record the resulting scale values.

## Operation of Brookfield viscometer:

1. To run RHEOCALC, type "rheocalc" at the DOS prompt. After a few seconds, the screen turns white and the following message appears:  
Checking RS-232 ports for Brookfield instruments...  
After determining which Brookfield instruments are connected, the RHEOCALC main screen appears.
2. Use the arrow keys to move the highlight bar in the main menu to the Setup option then press the Return/Enter key to open the Setup menu.
3. Choose the Zero Rheometer option in this menu. A message box appears asking you to ensure that there is no spindle attached to the rheometer. After removing spindle (if one was attached) and acknowledging with a keypress, the rheometer begins its auto-zeroing process. When auto-zero is complete, a message box reminds you to attach desired spindle, and press any key to continue.
4. Choose the Change spindle option in the Setup menu.
5. If all desired spindles are not on the spindle list consult page 8 of instruction manual.
6. Use the arrow key to select the spindle you wish to use in your data gather. Press the Return/Enter key to accept your selection.
7. Press the Escape key to close the Setup menu and return to the Main Menu. Select the Gather option from the Main Menu.
8. Select the Program option from the Gather menu. From the Program menu, select Geometric.
9. From the Geometric program menu, select the New Program option. At this point you are asked if you wish to run an Up/Down program. For this lab press "Y" key to answer yes.
10. The geometric program window opens to the left. This window requires the entry of four program parameters: a) Start RPM b) End RPM c) Step RPM d) Time Interval. Use the appropriate keys to enter the above parameters. To cycle through the four entry fields, use the Tab key. Allowable RPM values are 0.1 RPM through 250.0 RPM with a minimum increment of 0.1 RPM. Time Intervals are entered in minutes and seconds (MM:SS), and all four digits must be entered (you need not enter the ":" as it is automatically inserted for you).
11. When program entry is complete, press Return/Enter key to accept program. Select the Begin program option from the Geometric program menu.
12. After each Time Interval has elapsed, a data point is taken and displayed in the Gather Data window before ramping to the next speed.
13. After program is complete Save the data.

## Procedure:

The procedure which follows entails fitting a power law model to the observed data using a linear regression applied to transformed data and estimating the parameters of the model using the regression coefficients.

1. For each pair of torque-angular velocity data points, convert the torque in % to torque in N·m and rpm to angular velocity ( $\Omega$ ) in rad/s. The torque factor for the Brookfield viscometer is  $0.6737 \mu\text{N} \cdot \text{m}/\%$ . The torque factor for the Haake is  $147 \mu\text{N} \cdot \text{m}/\%$ .
2. Calculate shear stress from the torque data using equation [1]:

$$\tau_w = \frac{T}{2\pi r_i^2 L_{eq}}$$

where:  $\tau_w$  = shear stress at the spindle wall ( $r = r_i$ ),  $\text{N}/\text{m}^2$ ,  
 $T$  = torque,  $\text{N} \cdot \text{m}$ ,  
 $r_i$  = spindle radius,  $\text{m}$ ,  
 $L_{eq}$  = equivalent length of spindle,  $\text{m}$ .

3. Take the natural log of both the shear stress and the angular velocity. This step accomplishes the transformation.
4. Determine the slope of the  $\ln(\text{shear stress}) - \ln(\text{angular velocity})$  data using a spreadsheet linear regression routine. The slope is the flow behavior index ( $n$ ).
5. Calculate the shear rate  $\gamma$  using equation [2]:

$$\gamma_w = \frac{2}{n} \frac{\alpha^{2/n}}{\alpha^{2/n} - 1} \Omega$$

where:  $\alpha$  = radius ratio,  $r_o/r_i$ ,  
 $r_o$  = cup radius,  $\text{m}$ ,  
 $\Omega$  = angular velocity of the spindle,  $\text{s}^{-1}$ .

6. Calculate the viscosity function  $\eta$  in cP ( $1000 \text{ cP} = 1 \text{ Pa}\cdot\text{s}$ ) using equation [3]:

$$\eta = \frac{\tau_w}{\gamma_w}$$

7. Determine the consistency coefficient  $K$  from equation [4]. The intercept used in this equation is that determined from the linear regression in step 4.

$$K = \frac{e^{\text{intercept}}}{\left( \frac{2}{n} \frac{\alpha^{2/n}}{\alpha^{2/n} - 1} \right)^n}$$

8. Graph both the shear stress versus shear rate and the viscosity versus shear rate.