Session 2793

Water Resources Engineering in Freshman Clinic Laboratory

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Abstract

The first-year engineering experience at Rowan University includes a multi-disciplinary course entitled Freshman Clinic. This introductory course includes weekly lecture and laboratory sessions. The laboratory portion allows the students an opportunity to experience four engineering disciplines (Civil/Environmental, Chemical, Electrical/Computer, and Mechanical) for three weeks each. In the Civil and Environmental Engineering laboratory sessions, students are presented with a different laboratory module each of the three weeks: Environmental, Structural, and Water Resources Engineering.

To date, two different modules relating to Water Resources Engineering have been developed: one dealing with open channel flow over a weir, and the other dealing with energy conversion associated with a hydraulic turbine. In both modules, students investigate the factors affecting fluid flow in a particular engineering system, and make measurements of hydraulic phenomena. This paper describes these hands-on introductory engineering modules.

Introduction

The engineering curriculum at Rowan University contains a core of Engineering Clinic classes (Clinics), which cross disciplinary boundaries and span the entire four-year undergraduate education. The origins of the Clinic program at Rowan have been described previously[1]. The content and nature of the Clinics vary, as shown in Table 1.

Table 1: Overview of Engineering Clinic Content

Year	Engineering Clinic Theme (Fall)	Engineering Clinic Theme (Spring)
Freshman	Engineering Measurements	Competitive Assessment
Sophomore	Discipline Specific Design	Interdisciplinary Design
Junior	Open-ended problem solving in small teams	
Senior	Open-ended problem solving in small teams	

The four engineering programs at Rowan (Chemical, Civil and Environmental, Electrical and Computer, and Mechanical) have a common curriculum for the freshman year. The first engineering course that students take at Rowan University is Freshman Clinic I, which occurs in the fall semester of their first year. This introductory course is intended to give students a hands-on introduction to the field of engineering, and includes weekly lecture and laboratory sessions[2,3].

The lecture portion of Freshman Clinic I focuses on developing students' problem-solving skills, engineering ethics, history of engineering, and career-building skills such as resume writing and mock interviews for summer internships.

The overall theme of the lab-portion of Freshman Clinic I is Engineering Measurements[4]. The laboratory portion allows the students an opportunity to experience each of four engineering disciplines for three weeks. In the Civil and Environmental Engineering laboratory sessions, students are presented with a different laboratory module each of the three weeks: Environmental, Structural, and Water Resources Engineering.

Water Resources Engineering Modules

To date, two different modules relating to Water Resources Engineering have been developed: one dealing with open channel flow over a weir, and the other dealing with energy conversion associated with a hydraulic turbine. In both modules, students investigate the factors affecting fluid flow in a particular engineering system, and make measurements of hydraulic phenomena. The open channel flow module was used during the Fall Semester 1999; the energy conversion module was used during Fall Semester 2000.

Open Channel Flow

In the Open Channel Flow module, students use small laboratory flumes to examine steady and unsteady, uniform and non-uniform flows. Weirs are placed in the flumes, and the height of water above the weir is related to the volumetric discharge. The total flow rate is measured by timing the collection of a known volume of water. Students then compare measured flow rate with that calculated using the standard weir discharge equation, and comment on any differences. In addition, students explore the concept of continuity and hydraulic jumps.

The objectives of this module are to:

- Observe steady and unsteady flow behaviors in a simple flume
- Control a flow by adding weirs of different heights in the flume
- Determine effect of weir heights on flow conditions by direct observation
- Quantify flows by measuring water levels and flow rates
- Understand the concept of *continuity*
- Determine the relationship between *flow velocity*, *cross-sectional area*, and *discharge*.

To achieve these goals, students work in groups of 4 or 5, each with a small laboratory flume.

Five of the flumes are available, so that class section of approximately 20-24 students can be accommodated.

The flumes are rectangular channels, with flow supplied by a pump at the upstream end, as shown schematically in Figure 1. The flow passes through a perforated baffle and over a sharp-crested weir. The water level downstream of the weir is controlled by a hinged overflow tailgate. The flumes are made from acrylic plastic, with a width of about 77 mm (3 inches), a depth of 100 mm (4 inches), and a total length of 1.2 m (4 feet). Weirs of different heights (50, 65, 80 mm) can be placed in the channel.

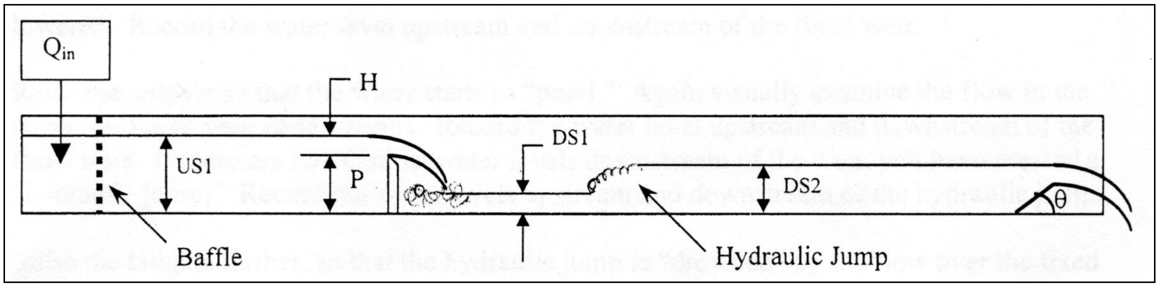

Figure 1: Experimental Flume Setup

Students investigate the effects of different discharge rates, weir heights, and tailgate angles. For each test condition, visual observations of the flow are made and sketches made in laboratory notebooks. Discharge is measured by recording the time required to fill a known volume (*e.g.* a bucket). Weir heights, and water levels upstream and downstream of the weir are measured with metric rulers. The flow rate in the flume is then calculated, based upon the traditional equation for weirs in open channel flow.

During the lab, the instructor circulates through the room, answering questions and directing students. Towards the end of the lab, the effects of a “killer weir” are demonstrated. The inspiration for this portion of the lab came from a set of labs described by Hotchkiss[5]. As the tailwater level is increased, the hydraulic jump downstream of the weir becomes submerged, creating a strong flow recirculation zone. This type of recirculation zone occurs in nature, and can pose a life-threatening danger to boaters and swimmers on small rivers. The phenomenon is demonstrated quite graphically, by placing a small plastic toy (*e.g.* a person or dinosaur) in the flow upstream of the weir. As the flow carries the toy over the weir, it gets caught in the recirculation zone, and may not be swept downstream past the drowned jump. When this occurs, the students learn how the age of dinosaurs *really* ended.

At the end of the lab period, students turn in copies of their raw data and preliminary calculated results. In addition, students must complete a group homework assignment, and answer the following questions:

1. Prepare a plot of tailwater elevation (downstream depth) as a function of tailgate position. In general, how does the tailwater level change with gate position?

2. Prepare a plot of downstream water level as a function of the water depth above the weir crest. Is there any relationship between the two?

3. Prepare a plot of your calculated discharge (using the weir equation) as a function of your measured discharge (from your timed volumetric measurements). Compute the ratio of Q_{weir} to Q_{timed}. If the ratio is not equal to 1.0, how can you reconcile the two? *(Hint: think about the discharge coefficient in the weir equation).*

4. Calculate the average flow velocity upstream and downstream of the fixed weir using your calculated value of discharge (based on the water level above the crest) and the cross-sectional area of the flow. How does the flow velocity vary in the flume for each test condition?

5. A hydraulic jump can be used as a way to dissipate energy in a flow. Speculate on why this might be true.

Figures 2 and 3 show students investigating the flow phenomena that occurred in their flumes.

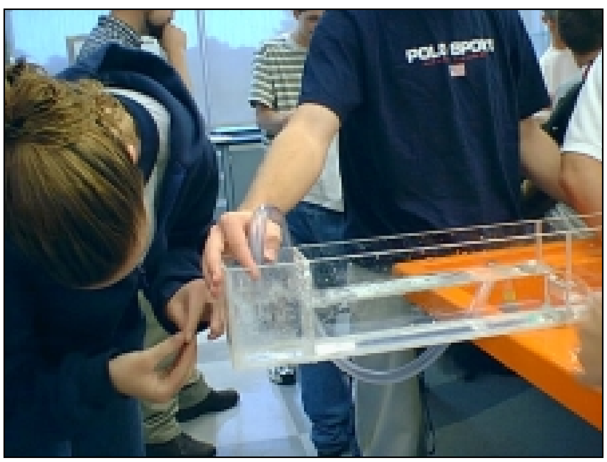

Figure 2: Flow upstream of the weir.

Figure 3: Flow downstream of weir, with hydraulic jump.

Energy Conversion with Turbines

This concept of *conservation* is one of the building blocks all of engineering and science. In engineering systems, properties such as mass or energy are not created or destroyed; they are merely transformed or transported, accumulated or exchanged.

In this lab module, students are exposed to the fundamentals of energy conversion to perform useful work. Students build hydraulic impulse turbines, and use the turbines to lift weights for determining power output. The overall objectives of this module are to:

- Learn about energy conversion
- Learn about unit conversions
- Understand the differences between force, work, and power
- Assemble a turbine
- Test the turbine by measuring the time required to lift different weights
- Document the tests neatly in lab books
- Have fun!

To achieve these goals, students work in groups of 3 or 4 to build their turbines from a standard set of parts. Six sets of materials for the turbines are available, so that class section of approximately 20-24 students can be accommodated easily.

The turbines are made from a set of standard parts, similar to those used in the Hydropower! Contest[6], held annually at professional society meetings. Each group receives a mounting board, impulse turbine wheel, bearings, nozzles, and flexible modular conduit. Working in groups, students "design" and build their turbine by selecting turbine type, nozzle configuration, and number of nozzles.

The completed turbines are tested on a custom-built test stand, which provides about 5 meters of head. The test stand is a 6-meter tall tower, designed specifically for evaluating the performance of hydraulic turbines. A reservoir on top of the tower provides water to the turbine via a hose. The flow from the reservoir to the turbine can be turned on and off by means of a ball valve. Water leaving the turbine falls into a lower reservoir, where it is pumped back up to the reservoir on top of the tower. A constant-head overflow tube is attached to the upper reservoir, to maintain a constant water level. A schematic of the Turbine Test Stand is shown in Figure 4.

The potential energy of the water stored in the upper reservoir is converted to kinetic energy of the spinning turbine, and is then converted to mechanical energy by lifting a weight. The weight is suspended from a pulley, and can travel roughly 4 meters. Each turbine lifts a series of weights, ranging in mass from 0.1 to 1.0 kilograms. The power developed by the turbine is determined by measuring the time required to lift different weights a fixed distance.

During the turbine construction portion of the lab, all student teams are working at the same time, comparing designs, and attempting to predict which turbine will produce the most power. During the testing, only one turbine can be used on the turbine test stand. However, all students in the class become actively involved, helping time the experiment, calculate power output, and mopping up the inevitable spray of water from the turbines.

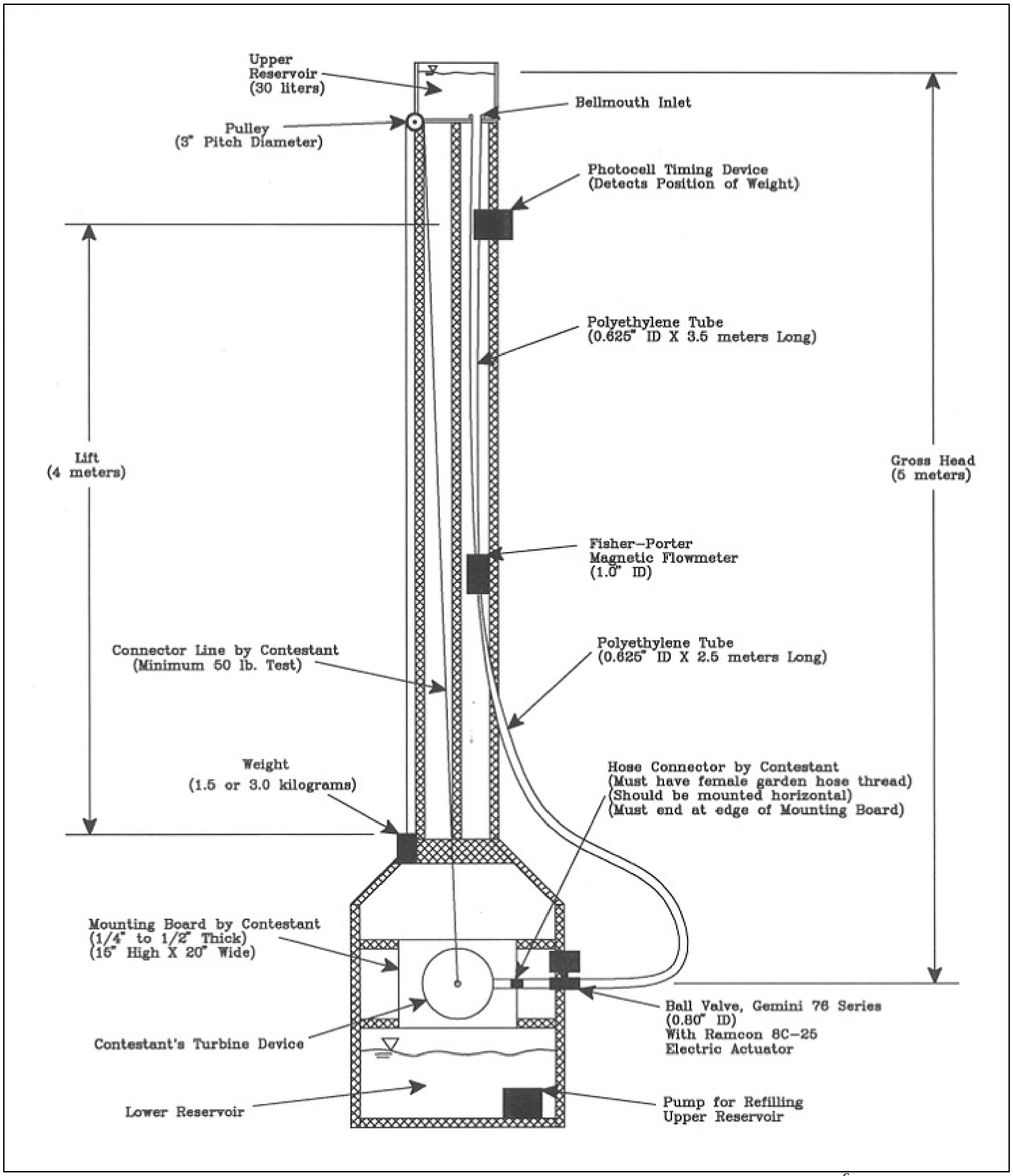

Figure 4: Schematic of Turbine Test Stand (from Hydropower! Contest[6])

At the end of the lab period, students turn in copies of their raw data and calculated results. In addition, students must complete a group homework assignment, comparing the performance of two different turbines, when mass and time data are provided.

Figures 5 – 8 show turbine construction and testing.

Figure 5: Turbine assembly.

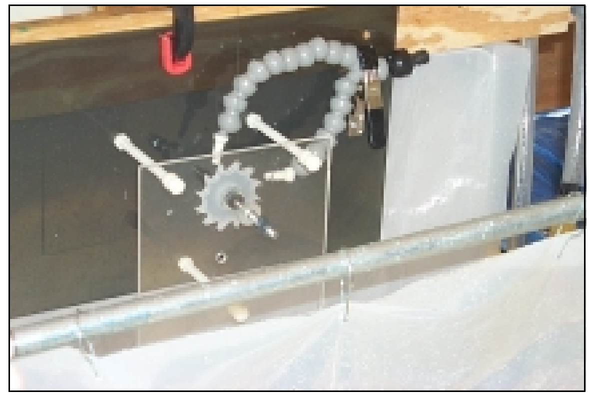

Figure 6: Completed turbine, ready to test.

Figure 7: Ready to time.

Figure 6: Test in progress.

Evaluation

Course surveys were given at the conclusion of each semester, to gauge student reactions to each of the modules, as well as to provide input for continual course improvements. Questions required responses on a scale from 1 to 5, with "1" corresponding to "strongly disagree" and "5" corresponding to "strongly agree." Specific questions included:

1. Material was presented in a clear and concise manner.
2. Experiments and/or in-class exercises were interesting and informative.
3. Handouts were informative and useful.
4. Homework was used as a vehicle to help you meet the objectives of the module.

Of these, the question that proves most useful in comparing the success of different modules is the second, relating to student interest. For this reason, all evaluations described here will focus on this question. Identical questions were used to evaluate all of the clinic modules, for both the 1999 and 2000 Fall Semesters.

In Fall semester 1999, the mean response on the survey for the Water Resources Engineering module (Flow Over Weirs) was 3.96. This compares to a maximum of 4.30 (for a Chemical Engineering module) and a minimum of 2.77 (for an Electrical / Computer Engineering module). The average of all module scores was 3.82. Of eight different modules for which survey results are available, the Flow Over Weirs module was ranked 4^{th}. Modules that elicited a more favorable response included two from Chemical Engineering and one from Mechanical Engineering.

The next year, the Water Resources Engineering module was changed from the weir experiment to the hydropower module. The mean response with respect to student interest for this module was 4.67, with a median value of 5. This was the highest-scoring module of nine evaluated; the second-highest ranked module had an evaluation score of 4.58. The average score of all nine modules was 3.97, with a minimum of 2.60 (again for an Electrical / Computer Engineering module).

The average score regarding student interest among all modules increased from 1999 to 2000, indicating that on the whole, all of the Freshman Engineering Clinic modules improved. The change in relative ranking of the Water Resources Engineering module from 4^{th} to 1^{st} is an indication that students preferred the Hydropower module to the Flow Over Weirs module. Possible reasons for this increase include a more dynamic module (moving water, weights, *etc.*) and the competitive nature of the hydropower module (groups trying to build the "best" turbine).

From an instructor's perspective, both modules are effective in demonstrating basic elements of water resources engineering, and both are enjoyable and challenging for the students. In future years, the modules may be alternated, to maintain freshness of presentation.

Summary

Two water resources engineering modules have been developed for the Freshman Clinic program at Rowan University, dealing with open channel flow and power conversions with turbines. The open channel flow module introduces students to various concepts of basic fluid mechanics (*e.g.* continuity, flow measurement, hydraulic jumps) through investigations of flow over weirs. The power conversion module provides experience with potential and kinetic energy via impulse turbines.

Student response to both modules was favorable, with a preference for the Hydropower module over the Open Channel Flow lab. Through these hands-on modules, that combine basic science and engineering principles with a fun activity, student interest is maintained, and lays a foundation for future coursework.

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