In-Class Demonstrations for Fluid Mechanics Lectures to Encourage Student Participation

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Overview

Two very important segments of an undergraduate fluid mechanics lecture course deal with flow in piping systems and pump operating characteristics. A portable demonstration unit has been designed and constructed to enhance the presentation of these topics and encourage active student participation in the learning process.

The demonstration unit is mounted on a small cart that can be readily moved to the lecture room. The unit consists of a pump, a water tank, and instrumentation to measure water flow rates and pressure drops. It also includes specimens of different types of piping/tubing (steel, copper), and different types of valves (gate, globe, and ball). A major feature of the demonstration unit is the easy interchange of test specimens through the use of quick-disconnect couplings.

The demonstration unit is run concurrent with lectures on friction factors and pressure drops in piping systems. During the class period, the students perform calculations and predict the pressure drops which should occur across lengths of piping for different water flow rates. Then the students operate the demonstration unit, and the actual pressure drops are measured. The students compare the pressure drops they have predicted using the text material with the actual pressure drops indicated by the demonstration unit. Similarly, measured pressure drops across different types of valves are compared to the pressure drops calculated using reference data from the textbook.

Pump performance characteristics; (i. e., head-flow curves) can also be determined in class for the two pumps included in the demonstration unit. The measured performance characteristics are then compared with the manufacturers specifications for the pumps.

Use of the demonstration unit along with lectures encourages active student participation in the learning process and improves the students' comprehension of the material.

This paper describes the demonstration unit in detail and includes a parts list. It also includes examples of class exercises which may be used in conjunction with the unit.

The Demonstration Unit

The demonstration unit is shown in **Figure 1**.

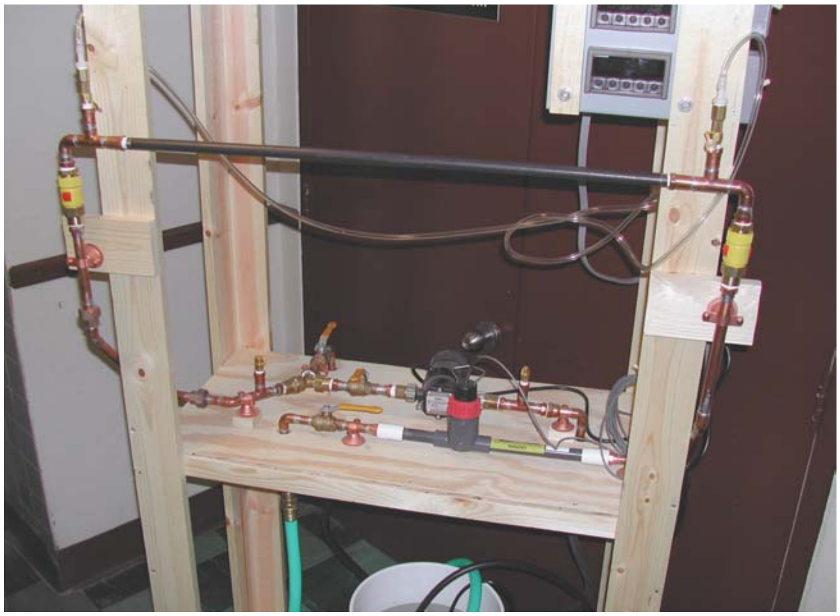


Figure 1 - The Demonstration Unit

The supporting structure of the demonstration unit consists of a wooden frame on a rolling platform. Components are either mounted on the frame or are located on one of the two shelves.

Two circulating pumps are provided. The pump to be used for a particular demonstration can be selected through individual electrical switches and proper positioning of valves. One of the pumps is mounted on the upper shelf of the unit. The other pump is a submersible pump located in a 5-gallon bucket on the bottom shelf of the unit.

In addition to the pump, the upper shelf supports the flow meter and connecting piping and fittings.

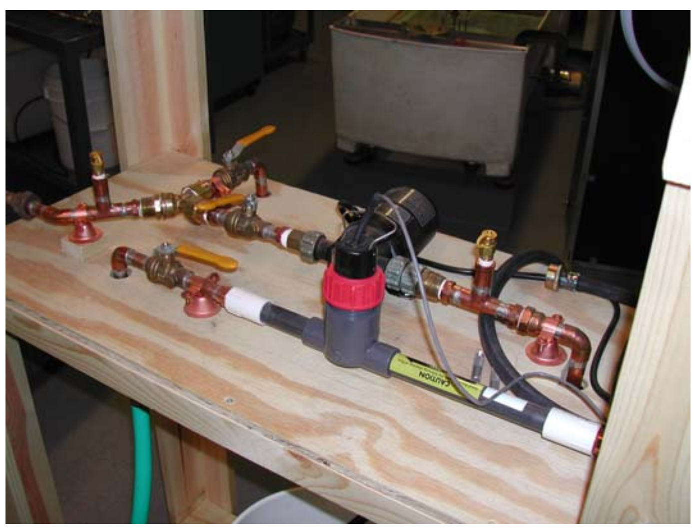
There are two digital meters mounted on the upper right corner of the frame. The upper meter indicates the water flow rate. The lower meter indicates the pressure drop between two selected points in the system.

Different test specimens can be mounted on the unit, and pressure drops across the specimens may be measured for different water flow rates. **Figure 1** shows a 3/8" Schedule 40 black pipe mounted as the test specimen. Other currently available test specimens include a copper pipe, and globe, gate and ball valves. Note the quick-disconnect couplings at the end of the test specimen. These couplings provide the capability for an unlimited variety of piping components to be mounted as test specimens. This easy interchange of test specimens is <u>the major design feature</u> of the demonstration unit. The quick-disconnects allow test specimens to be easily and rapidly changed.

Also note the plastic tubing leading to the pressure taps at the two ends of the pipe specimen. There is a pressure probe connected to the end of the tubing. The probe is inserted into the self-sealing test plug at the desired pressure tap location. The probes attached to the plastic tubing can be readily and quickly removed from and inserted into the test plugs, affording easy change of pressure measurement location. Each test specimen has two pressure taps – one at each end of the specimen. There are also pressure taps on the outlet piping from the two pumps. These pressure taps can be seen in **Figure 1.**

There are three (3) ball valves located on the shelf. One valve is used for flow control. The other two valves are used for pump selection.

Figure 2 gives a close-up view of the components mounted on the upper shelf of the unit. The flow meter is in the foreground and a pump is directly behind the flow meter.



<u>Figure 2 - Components on the Upper Shelf</u>

Figure 3 gives another view of the piping system.

Figure 3 - Components on the Upper Shelf

The plastic tubing from the pressure taps runs to the differential pressure sensor mounted on the frame of the unit. **Figure 4** shows this pressure sensor. It also gives a close view of a test specimen quick-disconnect.

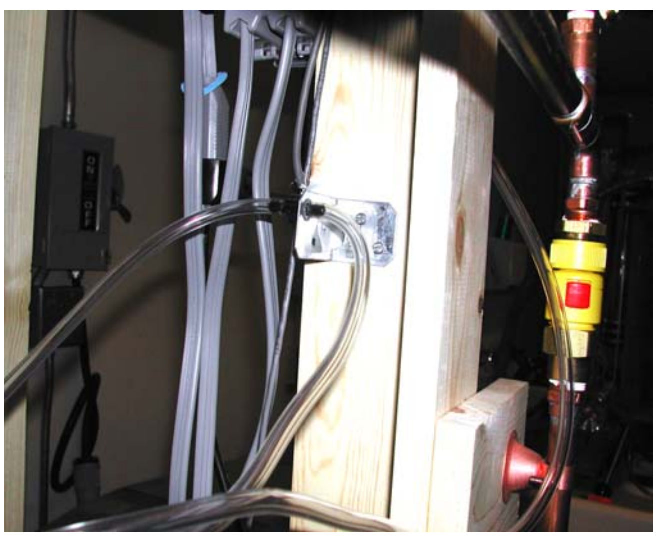


Figure 4 - Pressure Sensor and Test Specimen Quick-Disconnect

Equipment and Instrumentation

The following is a list of equipment and instrumentation items, including estimated costs:

EQUIPMENT ITEMS

QTY.	DESCRIPTION	PRICE
One (1)	Metal bottom frame with wheels. (Obtained from an office supply store. Item designed for moving of filing cabinets.)	$ 60
One (1)	Flotec 1/12 HP Pump Model FP0F360AC-08 (from Home Depot)	$ 70
One (1)	Flotec 1/6 HP Submersible Pump (from Home Depot)	$ 75
One (1)	Paddle Wheel Flow Sensor (Omega Engineering #FP-5300)	$ 250
One (1)	Fitting for Flow Sensor (Omega Engineering #FP-5305)	$ 150
One (1)	6-digit Flow Rate Meter (Omega Engineering #DPF-701)	$ 260
One (1)	Differential Pressure Sensor (Omega Engineering #PX26-015DV)	$ 35
One (1)	4-Pin Connector for Pressure Sensor (Omega Engineering #CX136-4)	$ 3
One (1)	Strain Gage Panel Meter (Omega Engineering #DP25B-S)	$ 245
Four (4)	Test Plugs (for pressure tap) (Omega Engineering #OPN014)	$ 38

Four (4)	Gage Adaptor Probe (for pressure tap) (Omega Engineering #GASS18)	$ 60
Three (3)	½" Brass Ball Valves	$ 15

Miscellaneous $ 150
Two (2) Quick-disconnects per test specimen
(Quick-disconnects are available from garden supply stores)
½" Copper Type M pipe and fittings
Electrical box and wiring
Drain and fill rubber hoses and fittings
Two (2) electrical switches for pumps
Electrical power strip
Wood for support frame

Use of the Demonstration Unit in Lecture Class

Being on a rolling frame, the demonstration unit is easily transportable to classrooms.

The demonstration unit is used during fluid mechanics lectures on pressure drops in piping and pressure drops across piping components such as valves. It is also used in lectures pertaining to pump performance characteristics (i. e., head-flow curves for pumps).

The instructor first discusses the theoretical aspects of either the pressure drops or the pump performance characteristics. If the subject is pressure drop, the appropriate test specimen is then mounted on the demonstration unit. The students are given the parameters for the test specimen. For example, if the test specimen is a length of pipe, the students are given the pipe size and material and also the water flow rate. If the test specimen is a valve, the students are given the type of valve, the percent opening of the valve, and the water flow rate. Using textbook equations and reference data, the students calculate the predicted pressure drop for the test specimen. The students then operate the demonstration unit and the actual pressure drop across the test specimen is measured. Comparisons are made between the actual pressure drop and the students' predicted pressure drop.

If the subject is pump performance, the demonstration unit is set-up to determine the head-flow curve for one of the two pumps on the unit. The students are given the manufacturer's head-flow data for the particular pump. The demonstration unit is then operated by the students to measure the actual head-flow characteristics of the pump. The observed pump performance is compared with the manufacturer's specifications.

The following are suggested demonstration unit runs which can be performed during the class period:

1) For a variety of flow rates, determine the pressure drops across lengths of pipe of different materials (e. g., steel, copper) and different diameters. Compare the observed pressure drops with theoretical predictions.

2) For a variety of flow rates, determine the pressure drops across different type of valves (e. g., globe, gate, ball) for different amounts of valve opening. Compare the observed pressure drops with theoretical predictions.

3) Determine the head-flow curves for one or both of the pumps included in the demonstration unit and compare the curves with the manufacturer's specifications.

4) The instructor provides the students with a section of piping that can be readily connected to the unit as a test specimen. The pipe section could contain valves or perhaps pipe fittings such as elbows and tees. Using the head-flow curve previously determined for a pump, the students predict the operating point (i. e., water flow rate) for the pump and piping system combination. The piping section is then connected to the demonstration unit, and the unit is operated. The observed operating point is compared with the predicted one.

Conclusions

Use of the demonstration unit in lecture class provides many benefits. With the students operating the equipment and performing calculations during the class period, a more visual and interactive environment is created. The classroom experience is more vibrant and exciting for both the students and the instructor. Through immediate comparison of the experimental results with the theoretical predictions, the students gain a better appreciation of the applicability and limitations of the theoretical and empirical information presented in the textbook.

In conclusion, it is believed that use of the demonstration unit in lecture classes significantly enhances the educational experience of the students and improves the students' comprehension of the lecture material.

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Charles H. Forsberg is an Associate Professor of Engineering at Hofstra University, where he teaches courses in the thermal/fluids area. He received a B. S. in Mechanical Engineering from the Polytechnic Institute of Brooklyn (now Polytechnic University), and an M. S. in Mechanical Engineering and Ph. D. from Columbia University. He is a Licensed Professional Engineer in New York State.