Session 2266

Development of Undergraduate Laboratories in Thermal-Fluids Area Through Student Involvement

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Introduction

The undergraduate mechanical engineering curriculum at Youngstown State University (YSU) currently requires the students to take three experiment-oriented 1-quarter-hour laboratory courses from the areas in applied thermodynamics, stress-strain analysis, heat transfer, fluid mechanics, vibrations, acoustics, and advanced machine design. These lab courses are offered at the senior level and the department's objective is to provide students with hand-on experience in modern measurement techniques, data acquisition, and extensive use of computers for analysis and reduction of experimental data. The lab courses, therefore, not only fulfill the pedagogic principle of validation of the engineering principles and laws, but also form an effective platform for enhancing the written and oral communication skills of our students through presentation of formal reports and oral presentations. In the lab courses that I teach in the thermal fluids area, I try to go beyond these basic objectives by providing students an opportunity to design and build new laboratory systems, or augment the existing equipment with modern instrumentation, and controls. In my lab courses, in addition to the conventional experiments during the weekly meetings, I assign one significant development project to student teams of two or three. The special project is assigned in the first week of the 10-week course to allow students sufficient time for the completion of their project. This paper discusses some of student projects, my philosophy behind the implementation of lab development projects, and the feedback I received from the students.

Philosophy

Traditional undergraduate labs usually concentrate on demonstrations of physical phenomena [Ref. 1]. As a result, when it is time to replace a particular equipment, the faculty member in charge of a lab, reviews the catalogs of engineering lab equipment vendors to determine which package best replaces the one on hand. Once a package and the vendor are considered, the professor then writes up a small proposal and submits it for consideration by the university administration. Invariably there are two main problems that are encountered: a) With the dwindling financial resources, the submitted proposal has to "compete" with several others from the department, college, and sometimes from the whole university for consideration in terms of urgency of the need for replacement, and (this is the bottom-line) the cost. The "canned experiments and packages" are usually very expensive. Therefore, the more expensive equipment is the lower the priority a request receives. b) The equipment may not allow sufficient flexibility for a more detailed parametric study of a principle. Besides, the laboratory experience remains relatively passive for the student. This does not imply that canned equipment packages can be completely ignored and that everything can be developed in-house. Sometimes the technological sophistication of the apparatus makes it imperative to buy rather than develop. However, there is a large class of experimental systems that can be developed by the students after the instructor specifies the important operating parameters of the end product. For example: a series-parallel 2-pump system. The students are given the maximum required flow rate and the head when the pumps operate in series, parallel, or when a single pump is running. A system like this can be bought for approximately $25,000.00. On the other hand, assign this project to a team of students, and the outcome is a good design experience, teamwork, and experience in active learning by actually selecting, buying, assembling, instrumenting, and testing the system they built. The material cost for building such a system may be about $1500.00 which is used as experimental apparatus by future students. The following sections describe some of the projects our students have completed in the fluid mechanics, and thermodynamics labs.

Fluid Mechanics Lab-ME 830L

I Design and development of converging, and converging-diverging nozzles and implementation of multiple pressure measurement and automatic data acquisition systems to measure axial pressure distribution in nozzles

The topics on one-dimensional compressible fluid flow, nozzle performance, and shock phenomenon are presented (Ref. 2) in a theory course in fluid mechanics – ME 830L. A group of two students was assigned the existing Techquipment Air-Blower system, which provided a specified flow rate at the 8-in^2 rectangular outlet. The students were to design a converging nozzle with maximum axial length of 18", and a converging-diverging nozzle – 32 inches long which could be attached to the blower outlet. They were then required to build these nozzles in our machine shop, and provide pressure taps for surface pressure measurements. Their nozzle design and the experimental arrangement are shown in Figs. 1 and 2 respectively.

The department had procured a Validyne variable reluctance pressure transducer-model DP103, the associated sensor interface card and software-UPC601-L, and a Scanivalve multi-pressure scanning system, called Fluid Switch Wafer-W0602. Another team was assigned the project of studying and implementing these two systems for measurement of pressure distribution in the nozzles. This project involved studying the characteristics of the electromechanical pressure transducer, wiring it to the power supply and the analog to digital board, installing the data acquisition software, and calibrating the transducer. The pressure wafer was also wired to the power supply. Another team developed interactive Visual Basic software, which introduces various hardware to a new experimenter and guides him/her through a step by step process of experimental process. The Visual Basic program activates the Pressure transducer through the data acquisition software when pressure measurements are to be made. The program then extracts the data from the UPC601-L software and stores it in the hard drive. The program then presents the reduced data through the MS Excel spreadsheet and graph. After each team completed their project, they integrated their work to conduct an experiment on pressure distribution in converging and converging diverging nozzle flow. The overall layout of the experimental setup is shown in Fig. 3. They compared the experimental pressure distribution with the one-dimensional isentropic nozzle flow. Their results are presented in Figs. 4 and 5.

Comments and Future Plan for the use of apparatus in I: The system developed by the students is not exclusively dedicated to the nozzle experiment. The whole system is mobile on a cart and can be used to make pressure measurements in other experiments and in other labs. Currently the pressure wafer is operated manually. The plan is to buy a Scanivalve Digital Interface Unit (SDIU) to control the scan cycle and place the measured values and address in memory which can then be retrieved by the host computer through IEEE-488. This will be another special project for a future team. The Basic program will also modified to display results in real time.

II Series-Parallel Pumping System

As previously stated, a team of students in the Fluid Mechanics Lab course was assigned a project to develop and test a two-pump system which can be operated as a) a single pump arrangement, b) a series arrangement, and c) a parallel arrangement. **The system** was to be equipped with appropriate piping and valves, a water storage tank, and pressure and flow gages. The important design constraint was that the material cost was not to exceed $500.00, an amount the department chair allowed. The students went back to their theory course on pump performance and operating characteristics, and proposed a layout. After consultations with me, they finalized the layout (Fig. 6). The pumps, and flow meter, which were a major expense, were selected from the Grangers Handbook keeping the cost factor in mind. The total material cost was $357.04 (Ref. 3).

Comments and Future Plan for the use of apparatus in II: The whole unit is on wheels. It is planned to demonstrate this working system during College open house, and high school student visits to campus. The pump motors currently run at constant rpm. A rheostat arrangement will be implemented in the future so that the pumps can be run at various flow rates and head. This will allow the construction of performance curves for the pump system.

III A hydraulic turbine cycle.

A group of students, at present, are working on a project to develop a small hydraulic turbine which will retrieve the kinetic energy from the water issuing from a small nozzle connected through a 1-in pipe to a storage tank at 15 ft elevation. The water after impacting the impeller blades is collected in a tank at the bottom of the turbine, and pumped back to the tank at the top (Fig. 7). The cycle thus continues. The project is in the final stages of completion. The students will be able to measure the turbine output through a small generator, compare the turbine output to the pump power input, and thus determine the conversion efficiency of the turbine they designed.

Comments and Future Plan for the use of apparatus in III: The turbine unit is another appealing demonstration unit for prospective engineering students to experience visually the concept of energy conversion, and what engineering is all about.

Thermodynamics Lab-ME 704L

IV Design and development of heating, humidification, and cooling duct

A team of students in the thermodynamics lab was assigned to design and build a long duct which was to have three sections: a heating section, followed by humidification and then by a cooling section. The available resources were a gas furnace fan, and an 18-inch diameter sheet metal duct, and thermometers. The required temperature increase in the heating section, the increase in the specific humidity, and the temperature drop in the cooling section were specified as design requirements. The students determined the heating power for the available fan discharge rate, and installed an electric resistance type heater. The humidification section was equipped with commercially available nozzle sprays (the ones used in the produce section of the grocery stores) connected to the water supply. In the cooling section, cold water was circulated through a multi-fin tube perpendicular to conditioned airflow. A simple schematic is shown in Fig. 8. The system was instrumented with dry and wet bulb thermometers.

Comments and Future Plan for the use of apparatus in IV: The HVAC system will be used to demonstrate the basic air conditioning processes to students in the theory class. In the subsequent lab course in Refrigeration and Air-Conditioning, the students will be able to conduct experiments and measure the psychrometric properties of air in the three sections for various heating, humidification, and cooling rates, and validate the theory. Some improvements in instrumentation are planned for future: the thermometers will be replaced by computer aided thermocouples. The fan on/off, and speed, the cooling water flow rate, and electric heater will also be controlled through controllers and computer interface. A comparable system if bought from lab equipment vendor would most probably be about ten times the cost. Besides, the value of active learning cannot be translated in dollars.

V Other smaller projects

a) Study of a small in-house steam turbine, measurement of electric power output, and steam inlet and exit properties using the existing instrumentation. Based on these measurements, the students are to determine the steam mass flow rate at full load and to install an appropriate steam flow meter after surveying the types of available meters. On completion of this project the students will be able to determine the conversion efficiency (at various loads) of the turbine, i.e., the ratio of actual turbine output based on enthalpy and mass flow rate consideration to the electric power output.

b) Installation of a jet engine fuel flow meter, which can be interfaced to a computer.

c) Installation of pressure and temperature gages at compressor exit, turbine inlet, and turbine outlet of a gas turbine (jet) engine in our lab. The 90-hp engine is connected to a water-cooled dynamometer; thus the students can conduct a load test. With the installation of a state-of-the-art fuel flow meter (the existing one is dated), and the pressure and temperature gages, the future class will be able to determine the power output and thermal efficiency of the engine from the first-law of thermodynamics (enthalpy consideration), and compare with the actual, i.e., BHP, and fuel consumption/heating value consideration.

Conclusions

Consistent with the ABET emphasis on design content through out the curriculum, extensive use of computers, written and oral communication, and team work, I try to incorporate all these aspects in my lab courses. So far I have seen a lot of enthusiasm in my students involved in the development projects after an initial brief period of apprehension, and uncertainty. A little reassurance and motivation by the professor go a long way in overcoming these mental obstacles. After successful completion of their projects, one could feel their sense of achievement. Comments such as “This was a unique experience for me here,” “I learned a lot in this lab,” and “the only turbine I had seen before taking this lab was the one drawn on the chalk board,” or “I wish we could have more of these projects,” are some examples of student feedback I received. There are occasional conflicts or lack of participation among team members, which I try to resolve through confidential one-on-one meeting.

Finally, the systems designed by students cost a fraction of that of a canned package. The designs also provide the flexibility in operations, and the instruments and software can be shared among other apparatus with minimal modifications.

Acknowledgement

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Bibliography

1. Renie, J. P., “Integrating Design of Experiments into Undergraduate Heat Transfer Laboratories,” *Proceedings of 1993 ASEE Conference*, University of Illinois, Urbana-Champaigne, IL, June 1993.

2. Fox, R. W., and McDonald, A. T., Introduction to Fluid Mechanics, 4th edition, John Wiley & Sons, 1992.

3. Fee, B., and Meszaros, A., “Development and Analysis of Flow Through Converging and Converging-Diverging Nozzles,” ME 830L lab report, June 1997.

4. Skurich, M., and Crown, K., “Series/Parallel Pumping System,” ME 830L lab report, June 1997.

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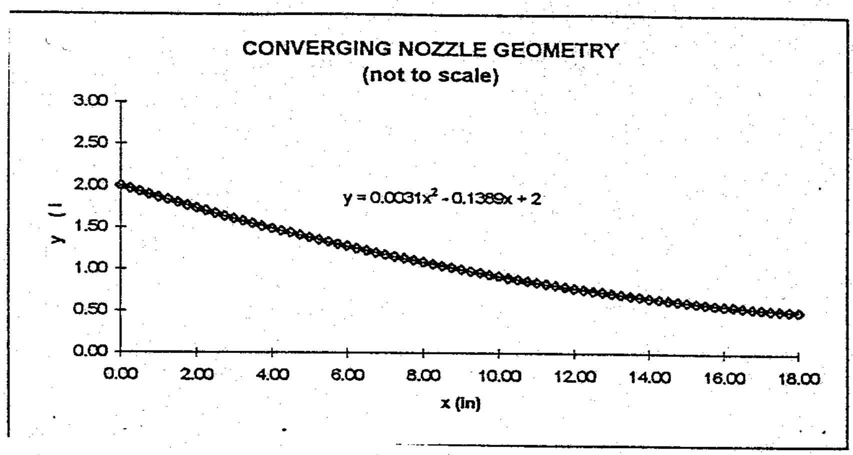

Fig. 1a: Converging Nozzle Geometry (Ref. 3)

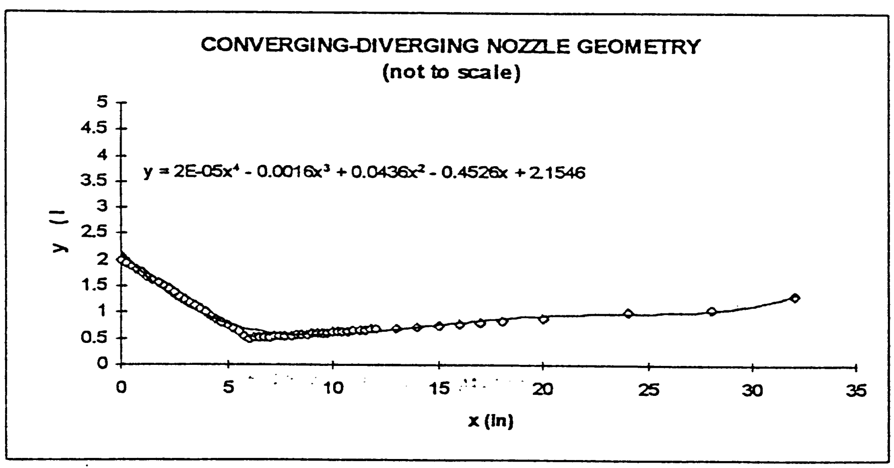

Fig. 1b: Converging-Diverging Nozzle Geometry (Ref. 3)

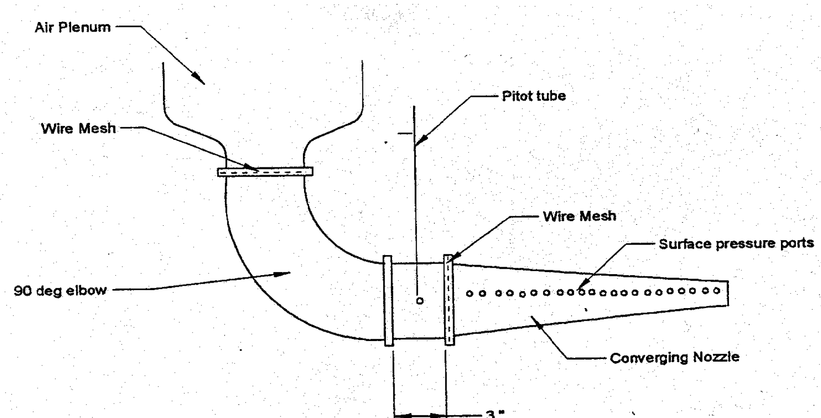

Fig. 2 The experimental arrangement (Ref. 3)

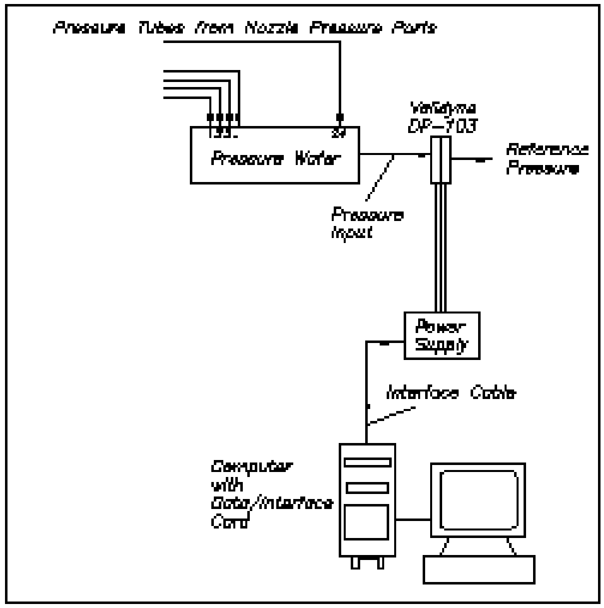

Fig. 3 Overall layout of experimental setup

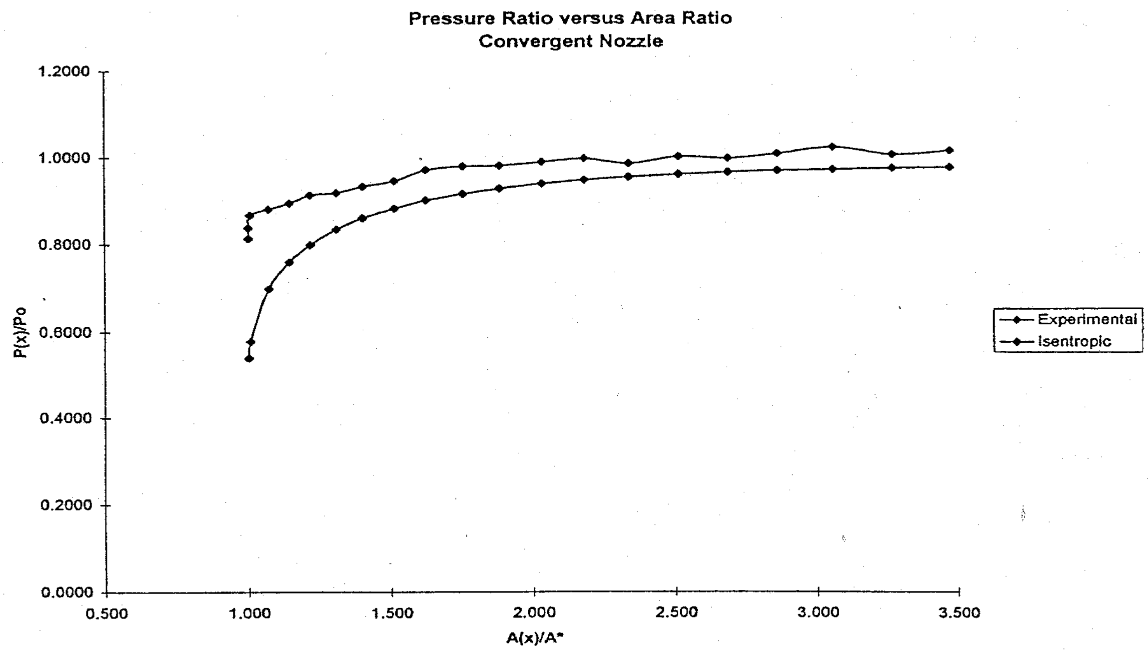

Fig. 4 Pressure distribution for converging nozzle

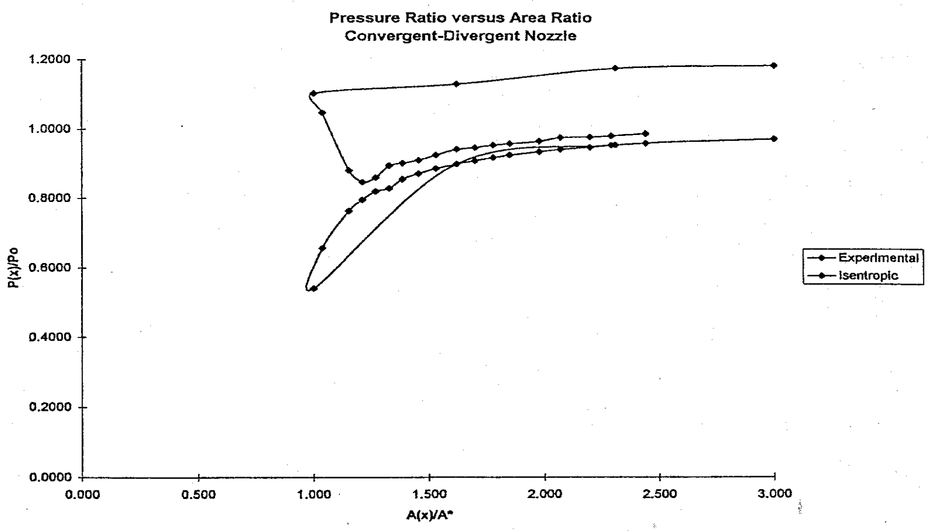

Fig. 5: Pressure distributions for converging-diverging nozzle (Ref.3)

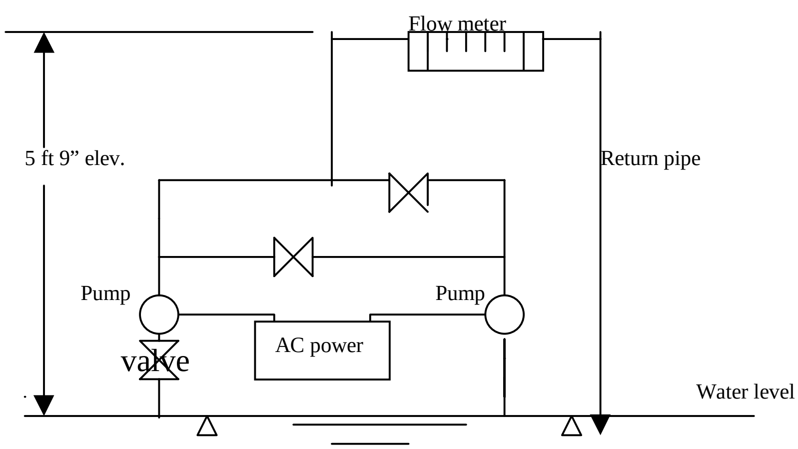

Fig. 6 The designed series and parallel pumping arragement (Ref. 4)

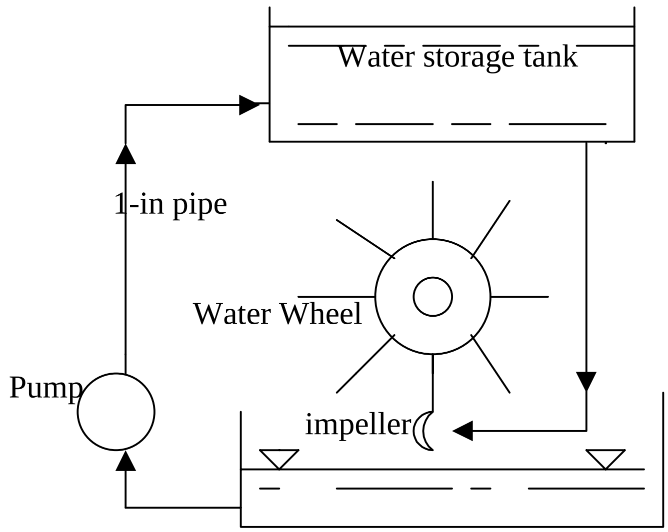

Fig. 7 A hydraulic turbine cycle

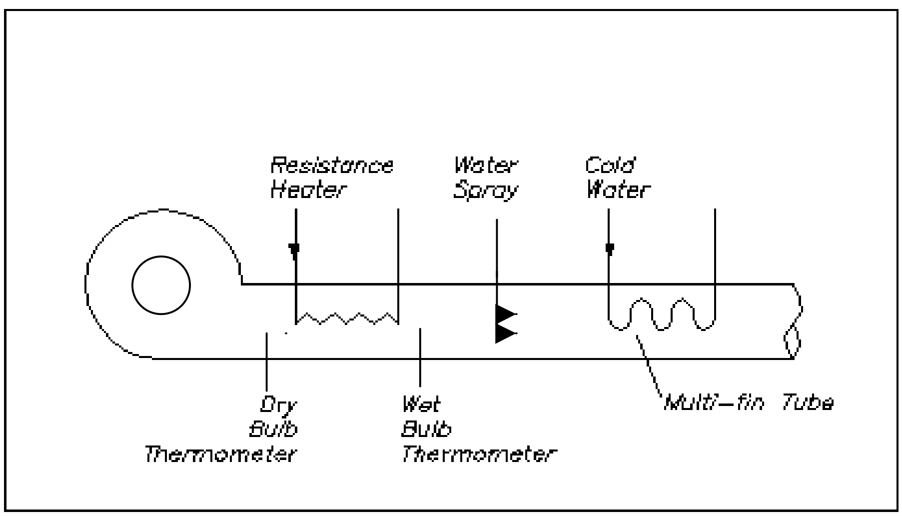

Fig. 8 Heating, humidification, and cooling duct