**Adam BARTNICKI, Tomasz MUSZYŃSKI**
Jarosław Dąbrowski Military University of Technology
adam.bartnicki@wat.edu.pl, tomasz.muszynski@wat.edu.pl

# MODERN LABORATORY FOR TEACHING BASIC LAWS OF FLUID MECHANICS

**Key words**

Fluid mechanics, flow, loss factors.

**Abstract**

Modern teaching laboratories help students acquire knowledge. Practical discovery of phenomena allows them to confront theoretical knowledge with practice. The paper presents modern teaching stations for analysis of fluid flow in hydraulic systems. They have been implemented into the teaching process at the Institute of Mechanical Engineering of the Mechanical Faculty of the Military University of Technology. They allow one to observe changes of energy occurring during the flow of a fluid. They make it possible to determine the coefficients of linear and local losses and other aspects of fluid mechanics experimentally.

## 1. Foreword

Discovering the essence of phenomena occurring in the world around us is the basis of civilization' development. This process can be carried out by theoretical or practical means. However, in most cases, both methods of these methods are used. This can be done according to two patterns. We either

observe a phenomenon or try to describe it with appropriate theoretical relationships, or create a theory and try to verify it experimentally. This approach offers a basis for the confirmation of the reliability of knowledge we have acquired. It gives a chance for further development of that knowledge and allows the general level of education of the society to be raised.

Combining theory and practice is also the best way to transfer knowledge. In this way, the student memorizes the themes worked on more easily. This is due to a greater number of stimuli and senses involved in the educational process. Thus, a larger number of various sensory information on the given phenomenon is saved in human memory. This translates into better consolidation of acquired knowledge. Individual traits must not be forgotten either. They can differentiate individual predisposition to the process of assimilating new information. In this case, the use of mixed cognitive methods ensures the high efficiency of the teaching process [3, 4].

Analysis of the methods of acquiring knowledge about the environment shows that the initial stage of human development is dominated by the experimental method. A child in infancy does not have the ability to speak or read, and yet it learns. It does it mainly by observation and independent repetition of certain behaviours. In other words, it carries out experiments allowing it to acquire and consolidate knowledge. This leads to the conclusion that this form of learning about the world is one of the most natural and easily assimilated forms of learning for the human being. As shown by teaching experience, this works well at every stage of education. Besides childhood, the second period of intensive use of this mechanism takes place in university. One could even say that it is an indispensable element, especially in technical studies. This is confirmed by the clear separation in the curricula of many subjects of laboratory classes as a form of teaching. It is there that students experimentally verify and complement their knowledge, acquired in the classroom.

For this form of teaching to bring the expected results, laboratories must be properly equipped. This means they need to have research stations that allow one to accurately recreate the phenomenon that is the subject of a class. The research stations must be able to clearly illustrate those phenomena, measure their characteristic parameters, and obtain results similar to the values determined theoretically. Another desirable feature is that the duration of an experiment can be adjusted to the duration of typical teaching modules.

## 2. Teaching area

One of the areas of teaching at the Institute of Mechanical Engineering of the Mechanical Faculty of the Military University of Technology (IBM WME WAT) is to familiarize students with the construction, use, and design principles

of hydraulic drive systems. This requires students to know the basic laws that govern the flow of liquids.

Most issues related to movement are discussed in secondary schools using the example of solids. This is due to a relatively easy to understand nature of this problem and quite simple mathematical relationships which describe it. Since the character of these schools is, in most cases, general education, this range of knowledge is quite sufficient. Universities are expected to educate students in strictly defined fields of study. This results in highly profiled courses. Students can therefore acquire much broader and detailed knowledge. This is essential in order to educate high-class specialists.

When considering technical aspects, such as energy conversion taking place in hydraulic drive systems, in order to achieve the intended teaching goal, students should be allowed to practically verify the discovered relationships and laws. This can be done only through laboratory classes. With this in mind, IBM WME WAT makes efforts to continually modernize its laboratories. In recent years, thanks to a grant from the Department of Science and Military Education, state-of-the-art research kits were obtained for the laboratory teaching of the subject discussed here.

## 3. Laboratory stations

The laboratory that has been set up offers an excellent laboratory base with which students can explore the phenomena occurring in hydraulic systems, identify features that affect energy consumption in the processes of fluid flow, set respective plant parameters, and evaluate the dynamic and hydrostatic impact of fluids on solids. The equipment includes top excellent teaching and research kits constituting the following [2]:

- A station for the analysis of cavitation effect;
- A station for determining the characteristics of positive displacement pumps;
- A station for determining the nature of liquid flow in hydraulic systems;
- A station for determining the impact of a change in the size of cross-section of installation on the potential and kinetic energy of liquid;
- A station for determining losses in a hydraulic piping installation;
- A station for determining losses in hydraulic valves with various designs;
- A station for determining losses in hydraulic ducts with various designs; and,
- A station for determining the dynamic response of a working fluid.

With the transparent casing of the pump at the station for the analysis of the cavitation effect, one can clearly observe the moment when air bubbles appear inside of it (Figure 1). The valves on the suction and discharge port can be used

to simulate varying resistances on the supply line and working line. In addition, the tank has a built-in system to control the temperature of the fluid circulating in the system. This allows for the analysis of a wide range of conditions in which cavitation occurs.

Fig. 1. Station for the analysis of the cavitation effect [1]

The station for determining the characteristics of positive displacement pumps can be used to determine the relationship between the capacity of a pump and the pressure generated by energy receivers (Fig. 2). Students using this station can precisely control the rotation speed of the rotor and simulate the load on the working line. In addition, the measurement system allows one to determine the value of power consumed by the propulsion engine of the pump, providing information about the efficiency of the analysed assembly.

Fig. 2. Station for determining the characteristics of positive displacement pumps [1]

The station for determining the nature of the flow of a liquid in hydraulic systems, by measuring the resistances and intensity of flow, allows one to identify the area of laminar and turbulent flow (Figure 3). To allow the precise measurement of pressure, a stabilized supply tank and a differential liquid manometer are used. For the area of the larger values of the Reynolds number,

a differential spring manometer is used, and the liquid is fed directly from the pump.

Fig. 3. Station for determining the nature of liquid flow in hydraulic systems [1]

The station for determining the impact of changes in the size of the cross-section of installation on the potential and kinetic energy of a liquid can be used to determine the course of the piezometric line and the energy line (Figure 4). In the system, it is possible to determine the speed of fluid flow in two ways: by measuring dynamic pressure and by measuring flow intensity. In this way, their mutual correlation can be assessed.

Fig. 4. Station for determining the impact of changes in the size of cross-section of installation on the potential and kinetic energy of liquid [1]

Measurements performed at the station for determining losses in the hydraulic piping installation can be used to evaluate how these losses are

affected by the various elements changing the direction of movement of the liquid (Fig. 5). The appropriately distributed ports for measuring pressure drop can be used to measure the drop of pressure on a single obstacle, and across the entire line.

Fig. 5. Station for determining losses in hydraulic piping installation [1]

This allows one to evaluate the impact of local disturbances of flow on the losses on straight sections.

Some of the most important elements of an installation are the valves. The value of losses generated by valves is closely related to their design. Valve characteristics can be determined using the station in Fig. 6. It features solutions using poppet and ball valve mechanisms. It is possible to draw up their characteristics as a function of the degree of distortion of lever/knob, interacting with elements changing the cross-section of the flow slot of the valve. Pressure drops are measured using very precise differential manometers, with a range of 2000 mBar and an accuracy of ± 1 mBar.

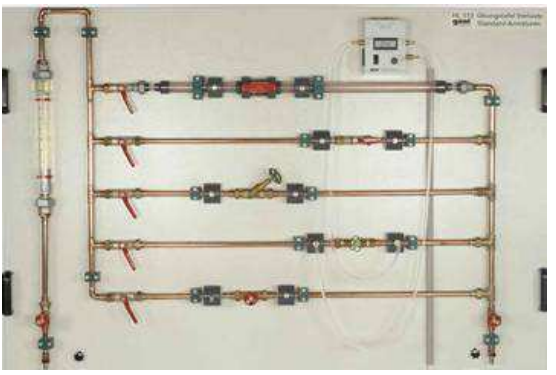

Fig. 6. Station for determining losses in valves with various designs [1]

The station for determining losses in hydraulic lines (Figure 7) allows one to evaluate the impact of the diameter and accuracy of the workmanship (radial irregularity of cross-section) of installation pipes on flow resistance.

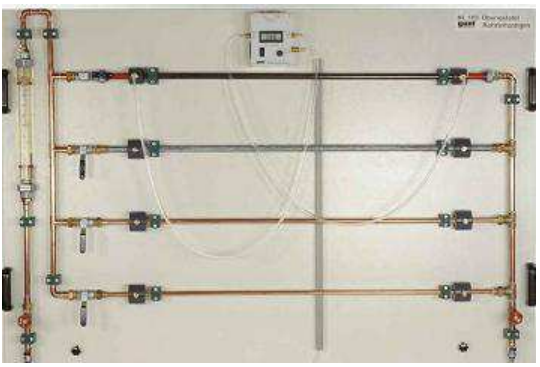

Fig. 7. Station for determining losses in lines with various designs [1]

The impact of the kinetic energy of the fluid on obstacles can be illustrated using the station for determining the dynamic response of working fluid (Figure 8). The various deflectors can be used to evaluate the efficiency of the whole process depending on the shape of the wall that is impacted by the fluid stream and the speed of its discharge from the system.

Fig. 8. Station for determining the dynamic response of working fluid [1].

Stations requiring an external source generating the movement of the liquid are supplied by the base module (Fig. 9). It has a centrifugal pump and two

tanks. One of them is used as a water reservoir, and the other serves a measurement function. Flow intensity is controlled by means of a throttle, using a ball valve installed on the delivery line. The station also includes additional connection elements, a stopwatch, and a measuring vessel for measuring small flow intensities.


Fig. 9. Base module

## Summary

The laboratory stations presented in the article meet all the requirements for educational research kits. This applies to security issues, repeatability, and the precision of measurements. In addition to issues strictly related to the research process, students also become familiar with the principles of the operation of hydraulic system components. They have an opportunity to become familiar with the problems of venting an installation, starting centrifugal pumps, and the impact of specific design solutions on the precision of controlling various measurement methods and devices. The experience they gain in this way will significantly enrich their knowledge and practical skills.

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**Nowoczesne laboratorium dydaktyczne do podstawowych praw mechaniki płynów**

**Słowa kluczowe**

Mechanika płynów, przepływ, współczynniki strat.

**Streszczenie**

Nowoczesne laboratoria dydaktyczne ułatwiają studentom przyswojenie wiedzy. Praktyczne poznanie zjawisk pozwala skonfrontować wiedzę teoretyczną z praktyką. W artykule zaprezentowane zostaną nowoczesne stanowiska dydaktyczne do analiz przepływu cieczy w instalacjach hydraulicznych. Wdrożono je do procesu nauczania w Instytucie Budowy Maszyn Wydziału Mechanicznego (IBM) WAT. Umożliwiają one obserwowanie zmian energii zachodzących podczas przepływu płynu. Dają możliwość doświadczalnego wyznaczania współczynników strat liniowych i miejscowych oraz innych aspektów mechaniki płynów.