Virtual Laboratory Work in the Course of Hydromechanics «Construction of D. Bernoulli's Diagram on a Pressure Pipeline of Variable Cross-Section by Seven Dimensional Cross-Sections of the Pipeline»

PRINCIPLES OF INTERACTION WITH THE VIRTUAL MODEL OF THE LABORATORY EQUIPMENT

The simulation model of the laboratory equipment is an interactive geometric structure placed in a virtual three-dimensional space. Observation of objects is carried out using a virtual camera. In the basic (free) mode, the camera can rotate around the focus point (figure 1). The focus point of the camera can move in the vertical frontal plane. In addition, the camera can distance itself relative to the focus point for an arbitrary distance bounded by the dimensions of the work space of 3D scene.

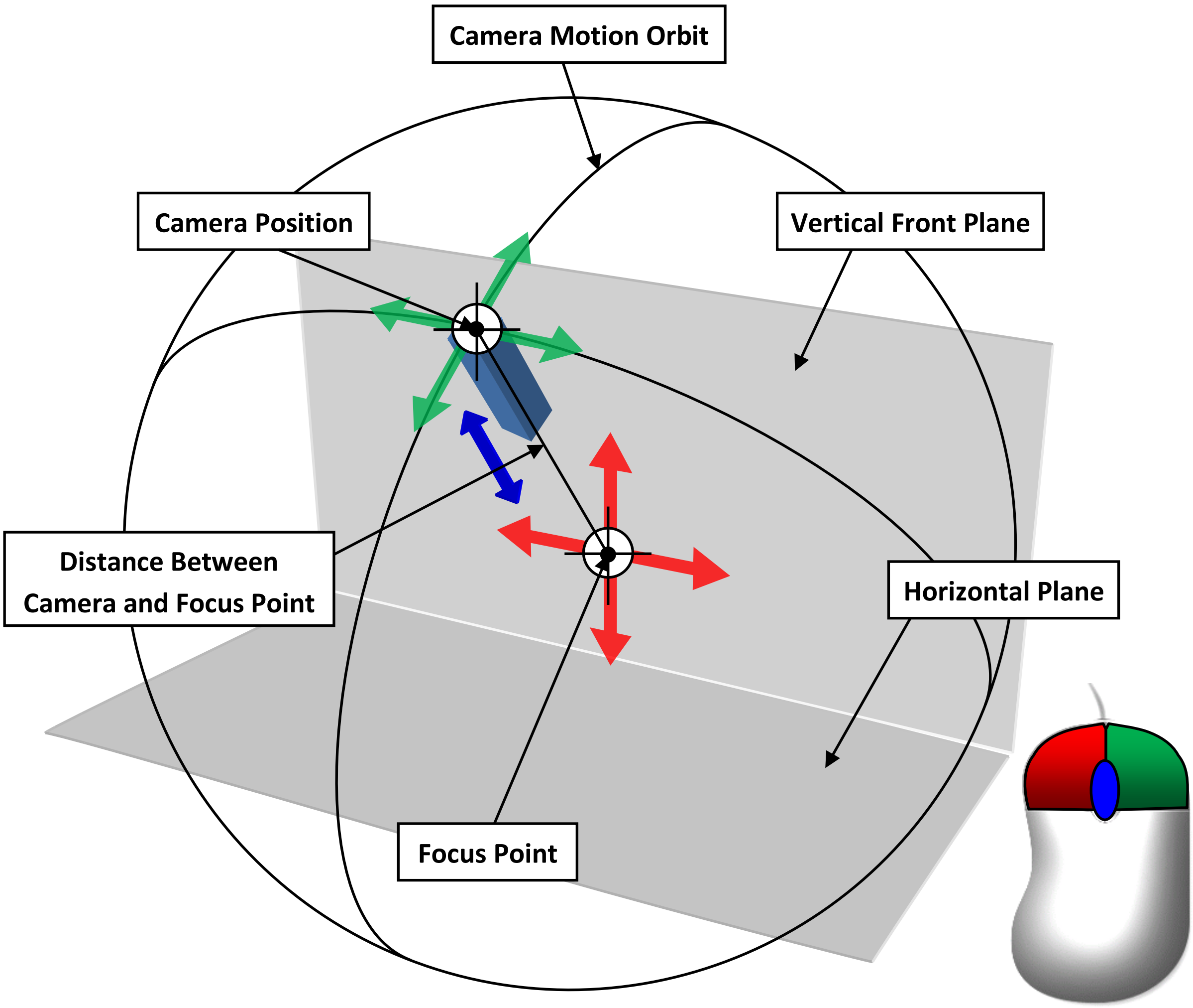

Figure 1 – Principle of the Camera Control in Free Mode

Basic manipulations with the camera in a free mode are carried out using a computer mouse. Herewith pressing and holding the left mouse button with the accompanying movement of the mouse moves the focus point of the camera in the frontal plane of work space. Clicking and holding the right mouse button while moving the mouse causes the camera to rotate relative to the focus point. The angles of rotation (azimuth and elevation) of the camera are limited by the dimensions of the 3D work space. The distance between camera and focus point is changing by rotating the mouse scroll wheel in the forward and reverse directions.

Note: in some virtlabs, the focus point may move in a horizontal plane!

In addition to the free mode, the camera can switch to individual elements of the laboratory equipment. Switching the camera to the individual object is performed by hovering the mouse over the object with a subsequent single click of the left mouse button. In this case, the camera can take a static position or be able to move in a vertical plane by hovering the mouse pointer to the edges of the screen or using the keyboard arrow keys. The clicking on an arbitrary area of the screen is return of the camera to basic mode.

The interaction with the control elements of the simulational laboratory equipment is carried out by hovering the mouse over the object and then pressing (or a single click) the left (or right) mouse button. Specific of the control for different elements may vary. For example, continuously regulating elements (flow control valves, etc.) require holding the left or right mouse button to change their state. Elements of discrete action (gates or latches) require a single click of the left mouse button.

At the moment of hovering the mouse pointer over the object, manipulations with the camera are temporarily unavailable. Similarly, when manipulating the camera, it is not possible to perform actions on the controls elements of the lab equipment.

VIRTUAL MODEL OF THE LABORATORY EQUIPMENT

A simulation model of a laboratory equipment (Figure 2) includes a pressure tank (1), into which water is supplied via a pipeline (2). The water supply is regulated by a valve (3). The pressure tank is equipped with an overflow system (4) to maintain a constant water level in order to provide a steady fluid movement in the pipeline of variable cross-section. Water from the pressure tank is supplied to a pipeline of variable cross-section (5). Piezometers and L-tubes (6) are connected to cross-sections I–I, II–II, III–III, IV–IV, V–V, VI–VI, VII–VII of the pipeline for measuring $z+\frac{p}{\rho g}$ and $z+\frac{p}{\rho g}+\frac{\upsilon^2}{2g}$. Changing the angle of inclination of the pipeline is carried out using a special protractor device equipped with a scale (7). The water flow in the pipeline is regulated by a valve (8). To measure water flow there is a measuring tank (9), water into which is directed by an overflow device, and a stopwatch.

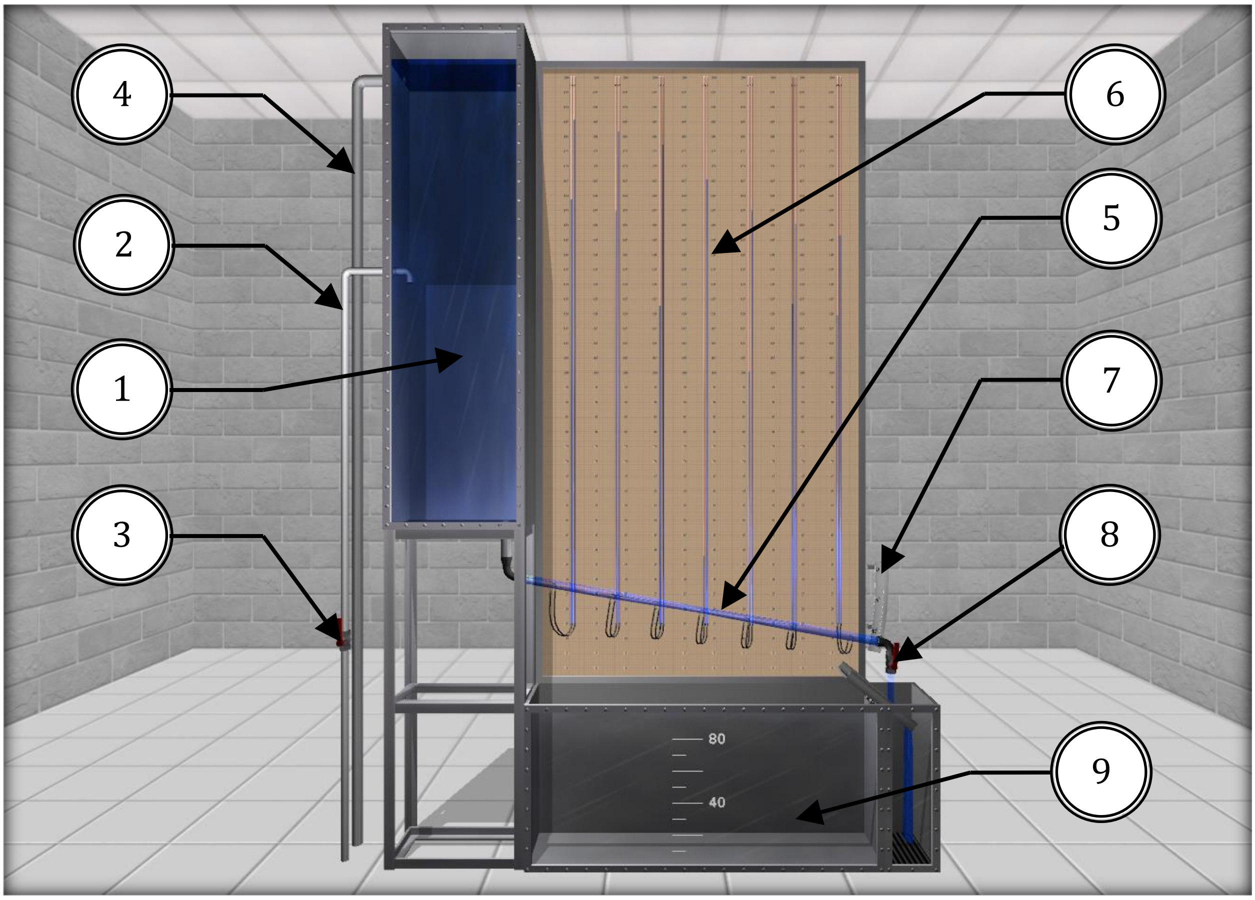

Figure 2 – Image of a Simulation Laboratory Equipment for Experimental Study of D. Bernoulli's Diagram on a Pressure Pipeline

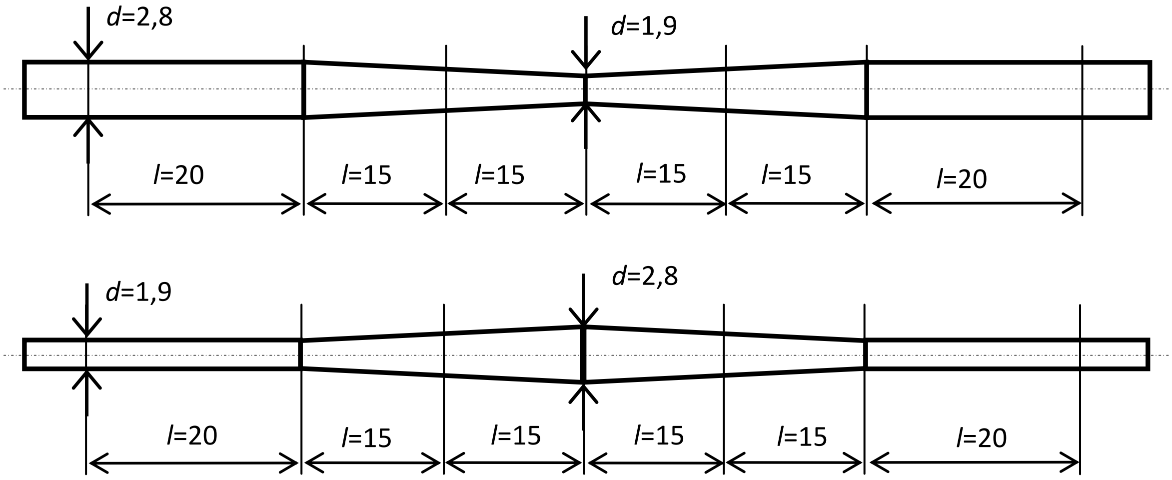

Figure 3 – Dimenstions (cm) of the Glass Tube with a Change in Cross-Section in the Middle Part with: narrowing (a) and extension (b)

At the beginning of the work, it is necessary to choose the type of glass section of the pipeline. Two types of glass tubes are available in laboratory work: with narrowing and expansion of the flow (Figure 3.a) and with expansion and further narrowing in the middle part along the length (Figure 3.b). By default, when starting the program, the tube type with narrowing in the middle part is set (Figure 4). Changing the type of pipeline is only possible if there is no water in the installation.

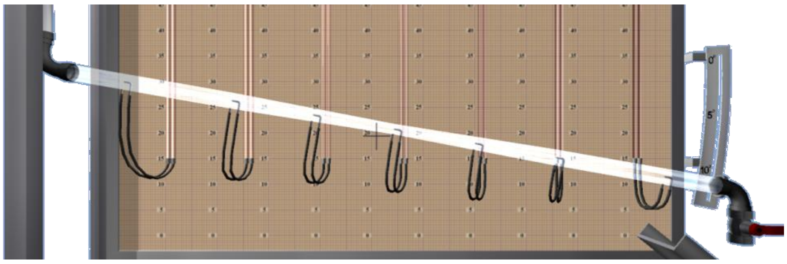

Figure 4 – Change the Type of Glass Tube

PHYSICAL PROCESS DESCRIPTION

The main points on the D. Bernoulli equation and its use in hydraulic calculations are described in the virtual laboratory work №3 «Experimental Determination of the Terms of D. Bernoulli's Equation at Steady Non-Uniform Motion of the Liquid».

In this lab work, it is proposed to pay attention to the behavior of the head and piezometric lines when the flow moves through a pipe with smoothly changing sections.

It is known that in a viscous fluid the total specific energy along the flow is constantly decreasing due to losses in overcoming the resistance (head line is constantly decreasing). The potential energy can either increase or decrease depending on the change in kinetic energy (with a change in the flow cross section). This is especially evident when narrowing and expansion of the flow are considered in comparison (Figures 5 and 6).

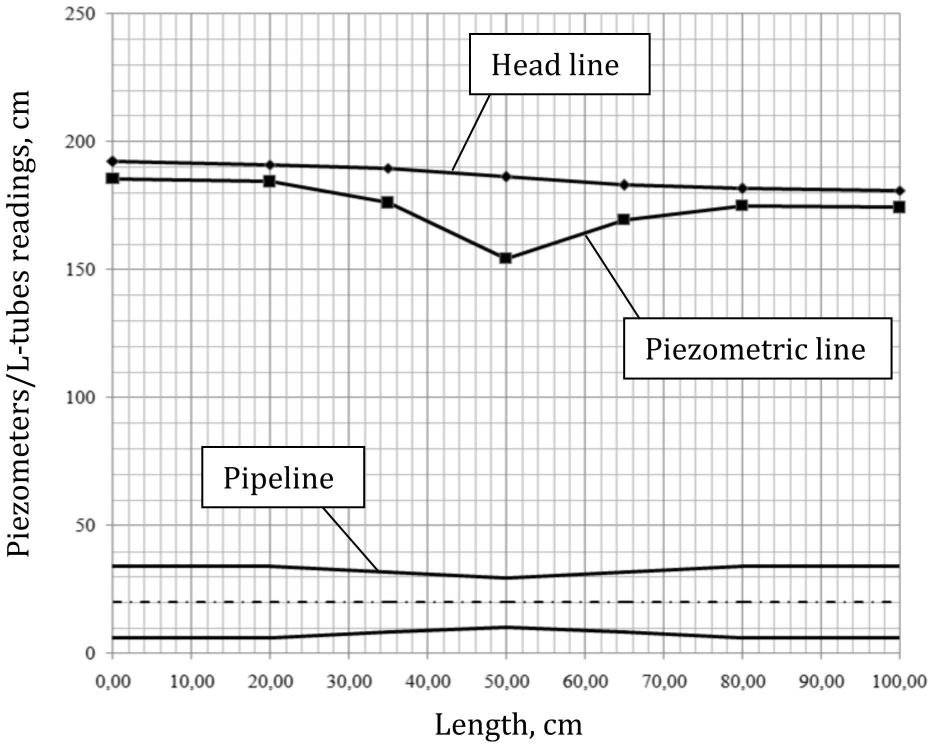

Figure 5 – D. Bernoulli's Diagram for Narrowing and Expansion of the Flow

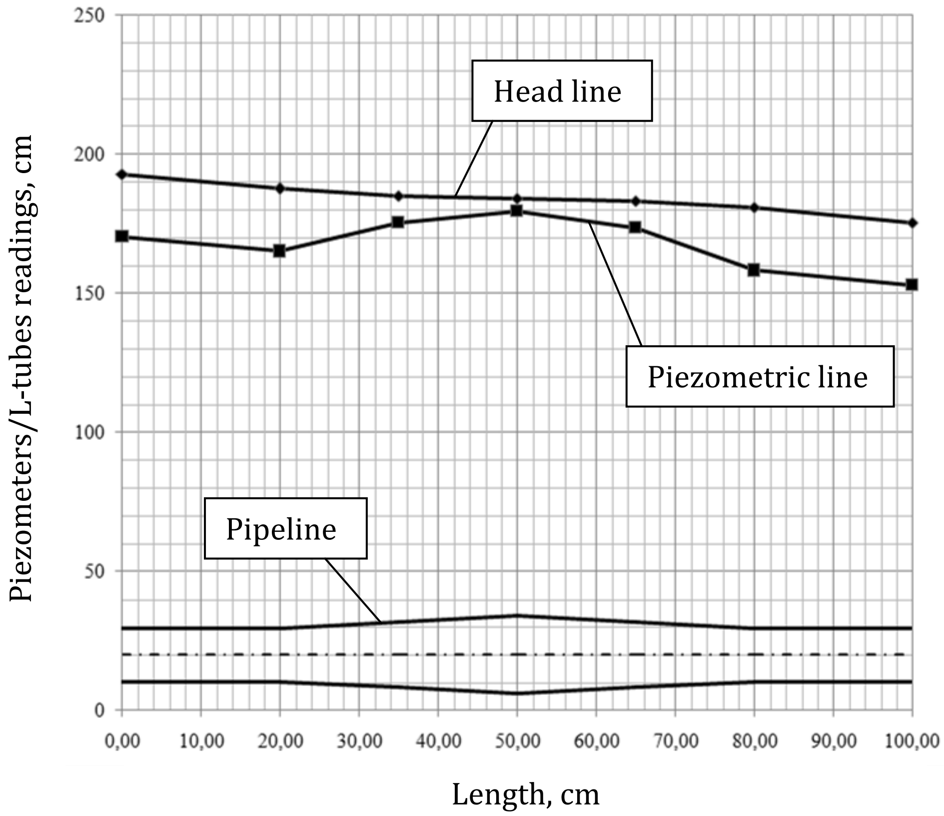

Figure 6 – D. Bernoulli's Diagram for Expansion and Narrowing of the Flow

LABORATORY WORK DESCRIPTION

Laboratory Work Objectives:

1. Determine the hydrodynamic and piezometric heads in the selected flow sections (seven sections).
2. Determine the head loss and the average velocity between the flow sections.
3. Build head and piezometric lines, analyze changes in specific energy.

The Order of the Work and the Processing of Experimental Data:

1. Before starting the equipment, select the type of glass section of the pipeline.
2. Record in the laboratory journal the areas of live sections and the distances between the sections indicated on the installation diagram.
3. With the flow control valve closed, open the water valve to fill the pressure tank and the variable cross-section pipe with water. In this case, attention should be paid to the water levels in the piezometric and velocity tubes. These levels in the absence of air in the system should be at the same level.
4. Open the flow control valve (from 5 to 100% as instructed by the teacher).
5. Use a measuring tank and a stopwatch to measure water flow.
6. Determine on a scale the water levels in piezometers and velocity tubes in seven sections. The results of all measurements are recorded in table. 1.
7. Perform all the calculations provided for in table. 1.

8. Construct a full-head line and a piezometric line on a scale from the data obtained.
9. Repeat steps 1–8 for another type of glass piping.
10. Give a conclusion of the results of the work.

Table 1 – Results of Measurements and Calculations

№	Measured and Calculated Values	Units	Experimental Results						
1	Section numbers		*I–I*	*II–II*	*III–III*	*IV–IV*	*V–V*	*VI–VI*	*VII–VII*
2	Geometric heights of the centers of gravity of cross-sections z_i	m							
3	The levels of water in piezometers tubes, i.e. hydrostatic heads $z_i + p_i/\rho g$	cm							
4	The levels of water in velocity tubes, i.e. full heads $H_i = z_i + p_i/\rho g + U_i^2/2g$	cm							
5	Piezometric heights $h_{pi} = p_i/\rho g$	cm							
6	Velocity heights $h_{ui} = U_i^2/2g$	cm							
7	Loss of total head on the path between adjacent living cross-sections of streams $h_{W_{i-(i+1)}} = H_i - H_{i+1}$	cm							
8	Total head loss	cm							
9	Distance between sections l_i	m							
10	Measuring tank volume W	m³							
11	Tank filling time t	s							
12	Water flow $Q=W/t$	m³/s							
13	Pipe diameter d_i	m							
14	Cross-section area $S_i = \pi d_i^2/4$	m²							
15	Average water velocity $\upsilon_i = Q/S_i$	m/s							
16	Velocity altitude corresponding to average speed $\upsilon_i^2/2g$	m							
17	Relative deviation $\frac{\left\lvert\frac{U_i^2}{2g}-\frac{v_i^2}{2g}\right\rvert}{\frac{U_i^2}{2g}} \cdot 100$	%							
18	The coordinate of the sections along the length of the pipeline	m							