Determination of Hydraulic Characteristics of Water Supply Networks

Guidelines for Simulation Laboratory Work

VirtLabs Software – 2020

INTRODUCTION

When calculating, designing, reconstructing and operating water supply networks, it becomes necessary to determine the actual hydraulic characteristics of individual sections of the network. During tests conducted for this purpose on water supply networks, free heads at different points of the water supply network, hydraulic resistance and throughput of its individual sections are determined, defective network sections, volumes of water losses on them and other indicators are detected.

Laboratory studies allow a deeper understanding of the basic laws of hydrostatics and hydrodynamics. The processing of a number of experimental data is carried out using diagrams and tables, the ability to use which is necessary for each engineer.

In the course of laboratory work, students gain practical skills in conducting tests on water supply networks in order to determine the hydraulic characteristics of the water supply network.

The instructions provide a methodology for performing simulation laboratory work to determine the hydraulic characteristics of the water supply network, contain recommendations for processing the results and requirements for reporting.

DESCRIPTION OF THE VIRTUAL LABORATORY «HYDRAULIC MODELING OF RING, DEAD END & COMBINED WATER NETWORKS»

Laboratory work is designed to simulate the experience of measuring the flow rates and hydrostatic heads of a water supply network. In this program module, there is no possibility of changing the configuration of the water supply system and the initial parameters of the experiment. The result of the module is the measured values of water flow and hydrostatic head at the nodal points of the water supply. After launching the program executable file, the process of loading graphic elements takes place. At the end of the loading process, the screen displays the working view of the model of the laboratory setup (Figure 1).

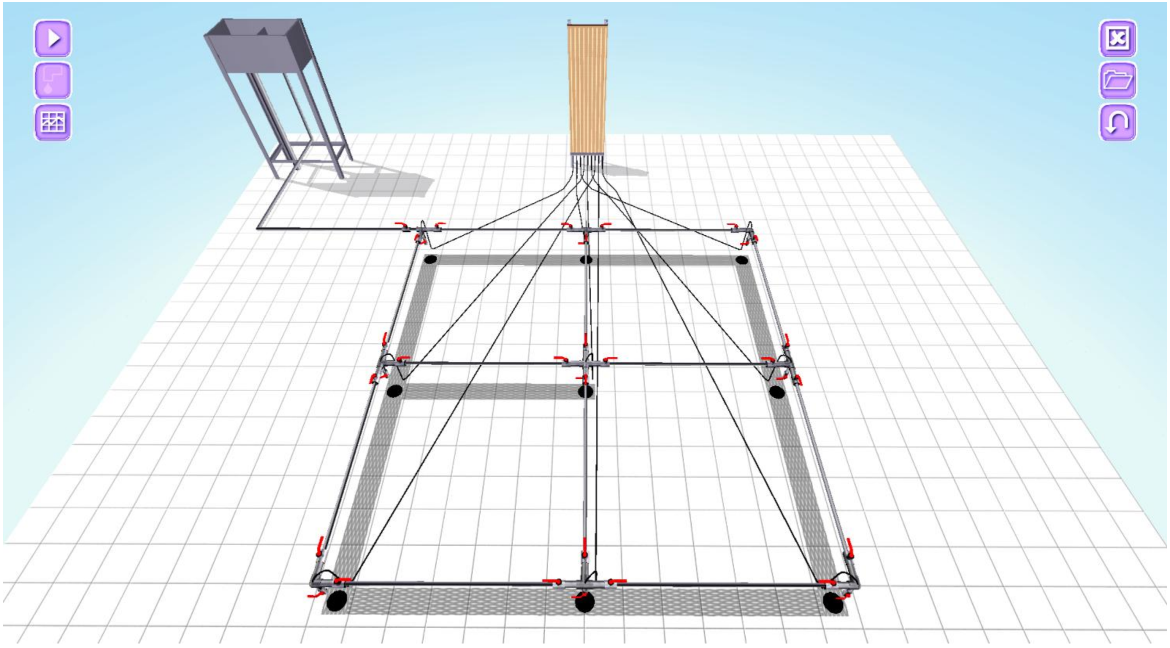

Figure 1 – General View of the Laboratory Work

The buttons are located in the upper right part of the screen (from top to bottom): «Exit the Program», «Open Model File», «Reset Parameters». The buttons are located in the upper left part of the screen (from top to bottom): «Fill the Equipment with Water», «Open the Drain Valves» and «Display the piezometric plane».

Lab work should begin by opening the parameter file by left-clicking on the «Open Model File» icon. After selecting and opening a pre-prepared parameter file, the pipeline configuration will change in accordance with the loaded parametric model (for example, Figure 2).

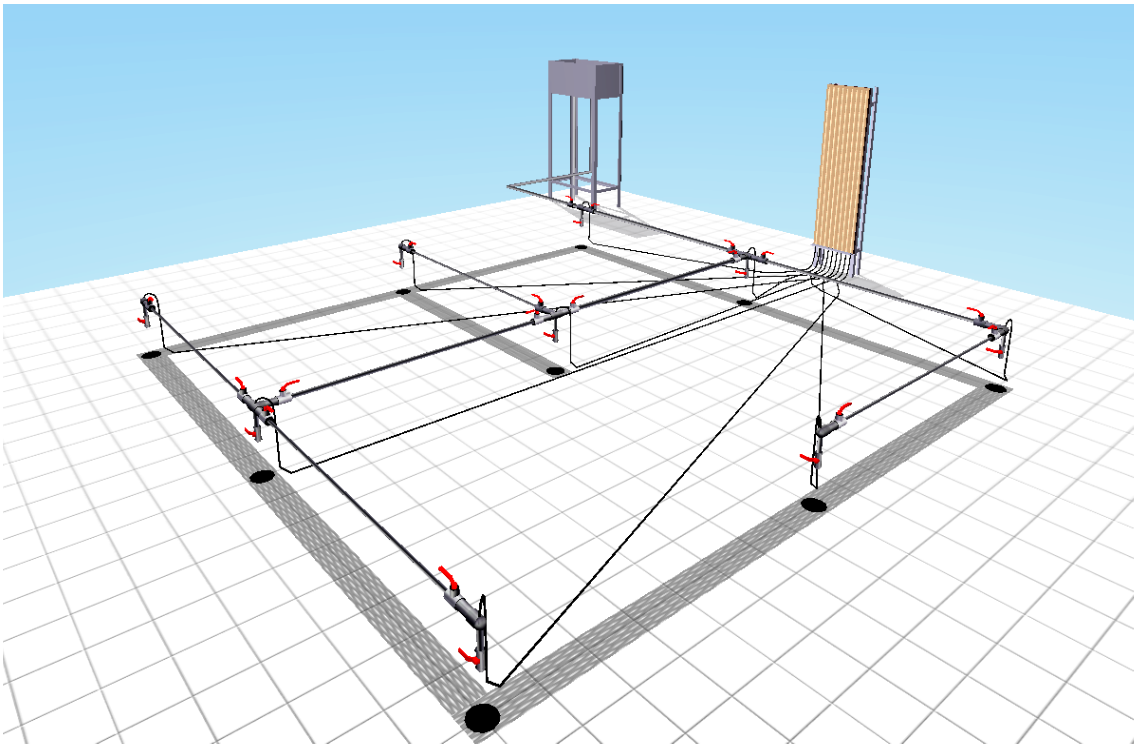

Figure 2 – Piping Configuration According to Loaded Parametric Model

After loading the model parameters, it is necessary to fill the equipment with water by left-clicking on the corresponding icon on the left side of the screen.

As a result of filling the installation with water, the «Open the Drain Valves» button will become available, left-clicking on it will lead to a change in the position of the triggering valves in accordance with the embedded parametric model.

Information about the state of all structural elements of the pipeline (lengths of sections, diameters, opening values of valves, etc.) is displayed when the mouse pointer hovers over the corresponding elements. The user captures the characteristic parameters of the pipeline and measures the hydrostatic heads using the piezometer stand, focusing on the millimeter marking of the stand.

To measure water flow at nodal points, you must move the mouse pointer over the corresponding jets of merging water and left-click. In this case, the virtual camera will switch to the flow metering mode at a specific nodal point (Figure 3).

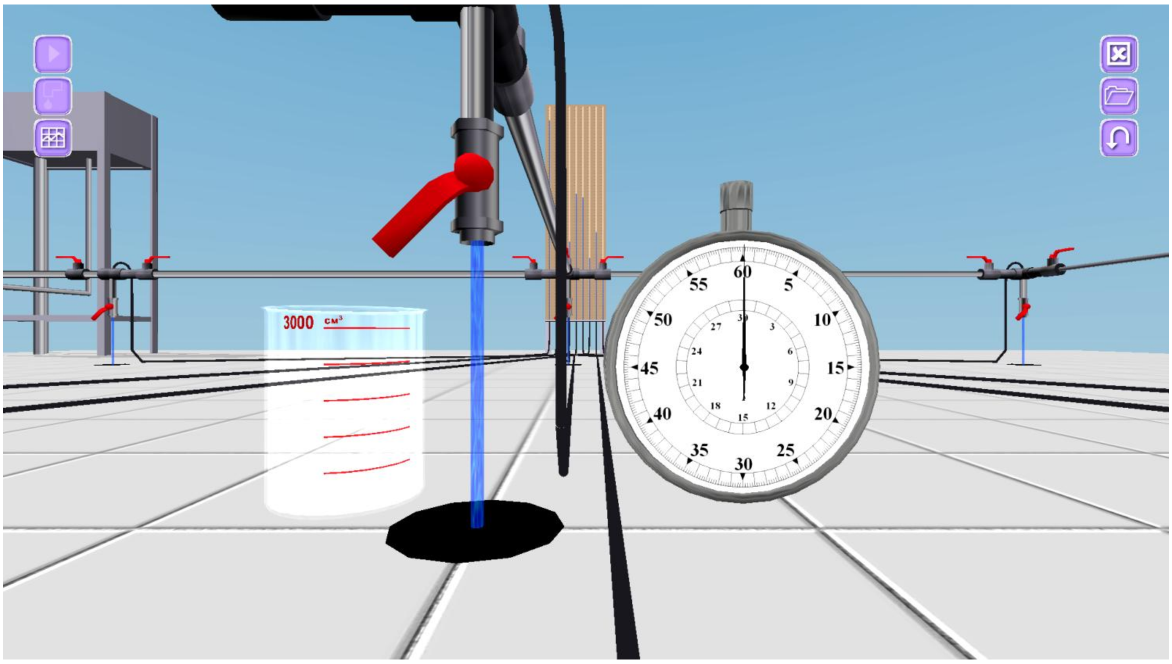

Figure 3 – Virtual Camera in Flow Rate Measuring Mode

To measure the flow rate, left-click on the three-dimensional object «Vessel». After filling the container, you need to fix the time, focusing on the calibration of the stopwatch dial (Figure 4).

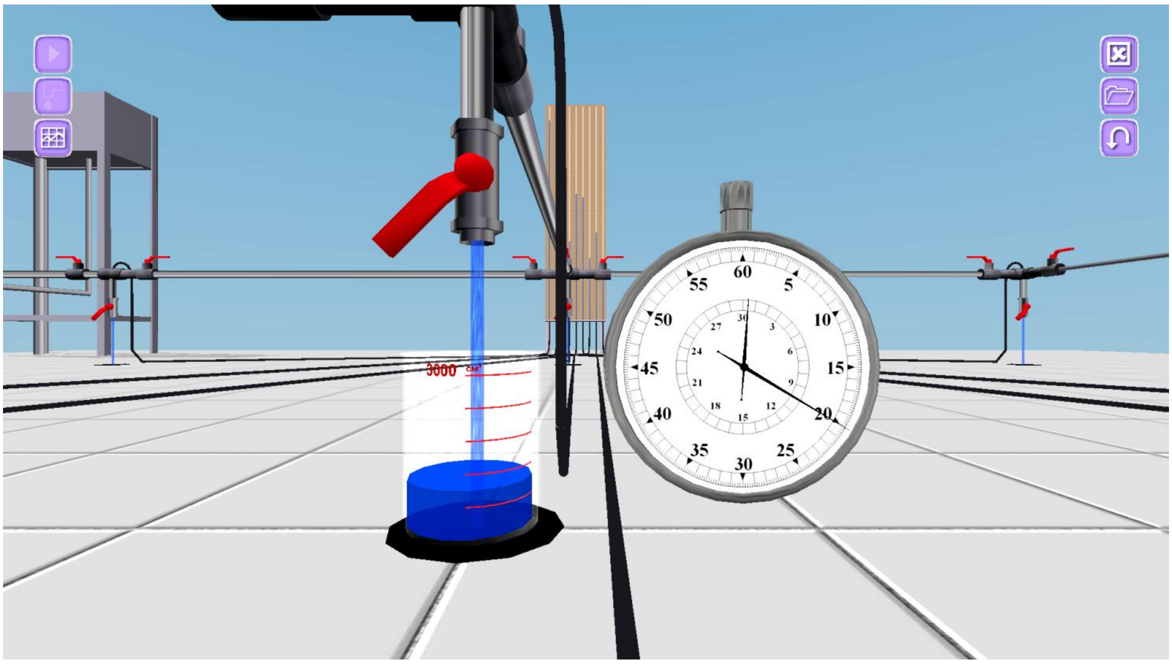

Figure 4 – Process of Measuring Water Flow at the Network Node

Return the camera to its original position by clicking with the right mouse button.

To display a piezometric plane on the screen – a graphical representation of the pressure heads at the pipeline nodes, hover the mouse pointer over the «Display Piezometric Plane» icon on the left side of the screen and click (without releasing) the left mouse button. The piezometric plane will appear on the screen as a blue outline of the surface and will be available for viewing as long as the mouse pointer is on the «Display Piezometric Plane» icon and the left mouse button is pressed (figure 5).

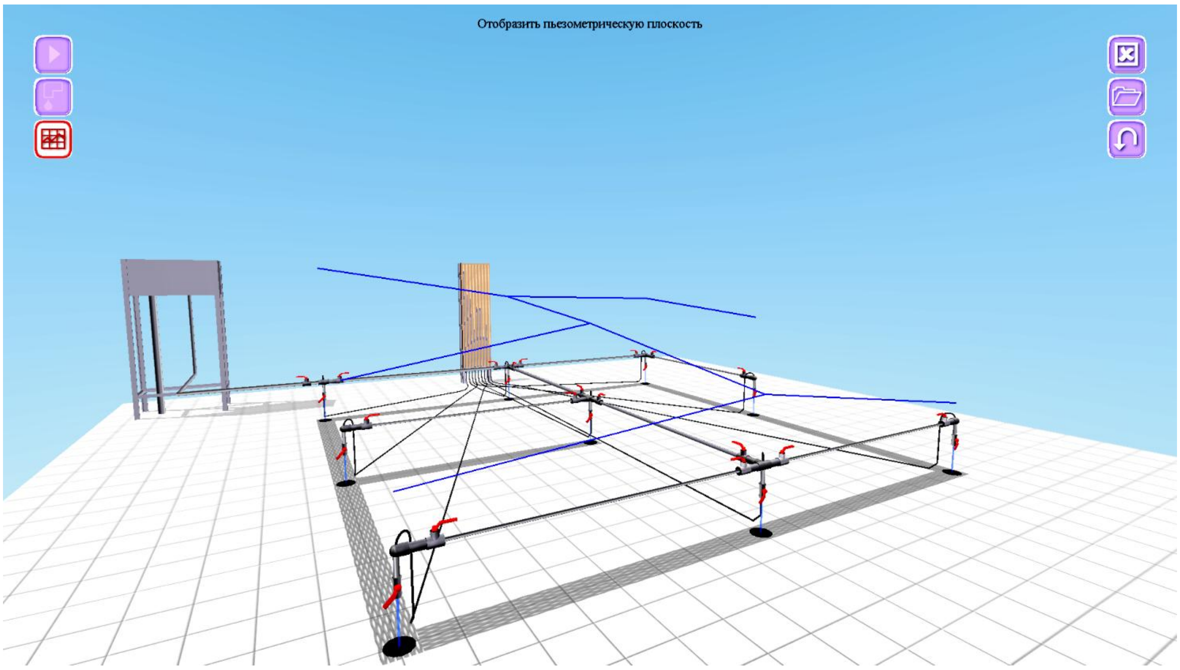

Figure 5 – Displaying the Piezometric Plane

The measured output parameters of the simulation model are entered by the user in a special laboratory log and processed in accordance with the test methodology. This completes the work of the virtual lab.

LABORATORY WORK №1
«Dead-End Water Supply Network»

1.1. General Information

Dead-end water supply networks are widely used in water supply systems of settlements and industrial enterprises. The water supply network must meet the following basic requirements:

– to provide water supply to places of consumption with a given pressure;
– possess reliability and ensure uninterrupted water supply.

1.2. Purpose of Work

Investigate the operation of a dead-end water supply network, as a result of which:

– build a piezometric line on the expanded profile of the network and determine the direction of movement of water flows in individual sections with unilateral power supply of the network;
– determine in an analytical way the linear flow rates of water;
– check the balance of the inflow and outflow of water in the nodes.

1.3. Equipment Description

Laboratory work is carried out on a model of a dead-end water supply network made of metal tubes with a diameter of 10, 15 and 20 mm, depending on the model file. The tubes are interconnected in a water supply network. To regulate the flow of water along the lines of the network in nodes 1 to 9, control valves are installed. Piezometric heads in each node are measured by piezometers mounted on a piezometric stand. Water is supplied to the network from node 1. During the laboratory work, it is required to determine the following installation parameters:

- nodal water flows – Q_i (i – node number)
- nodal hydrostatic heads – H_i
- geodetic heights of nodes – Z_i
- water flows of network sections – q_{ij} (ij – section number)
- water velocities of network sections – V_{ij}
- head losses of network sections – h_{ij}
- length of sections – L_{ij}
- diameters of the sections – D_{ij}

Figure 6 shows the scheme of a dead-end water supply network in the plan.

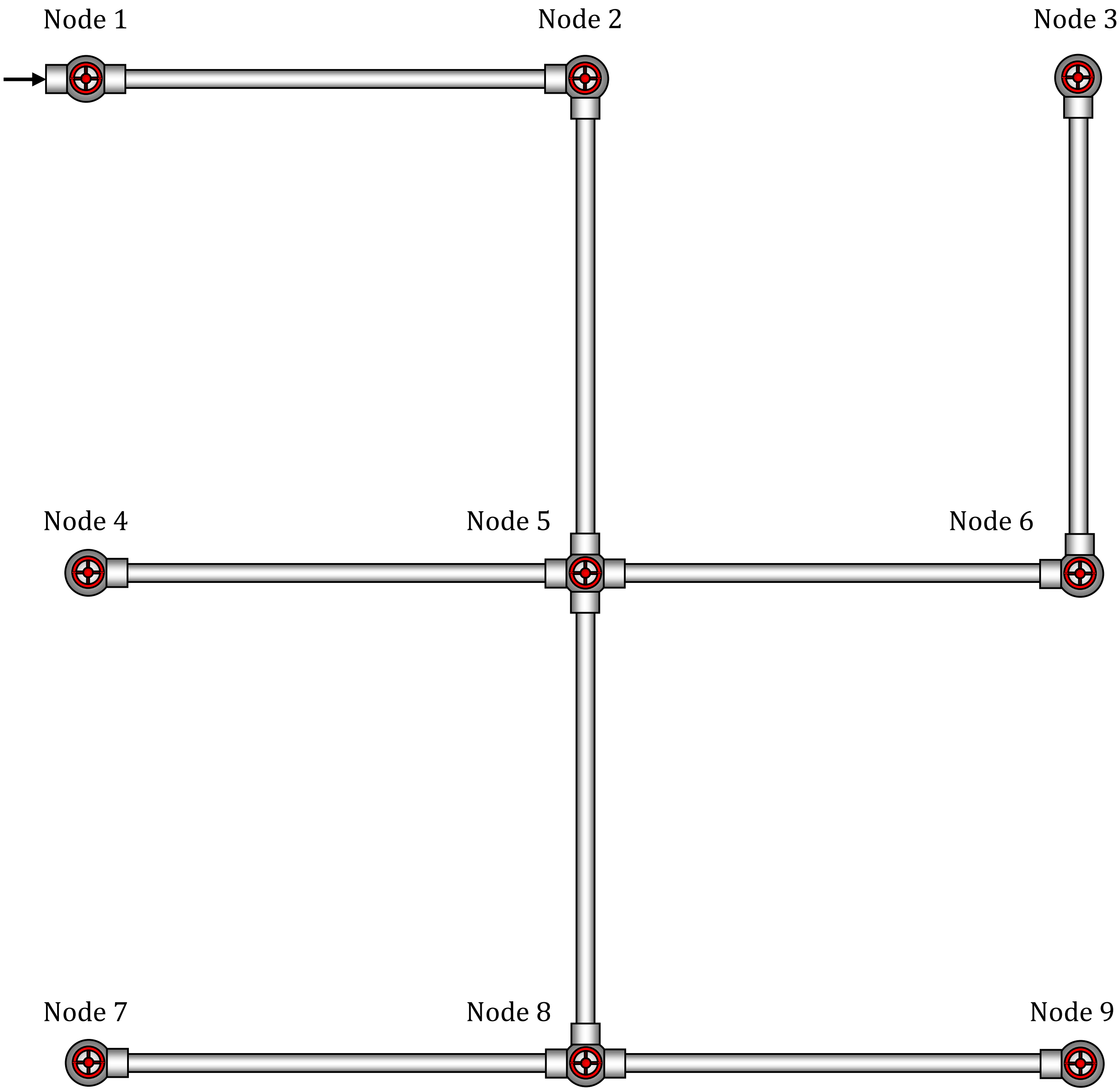

Figure 6 – Scheme of a Dead-End Water Supply Network

1.4. Lab Work Order

To pass water along the lines of the network, it is necessary to open all the drain valves located in the nodes of the network (Figure 7).

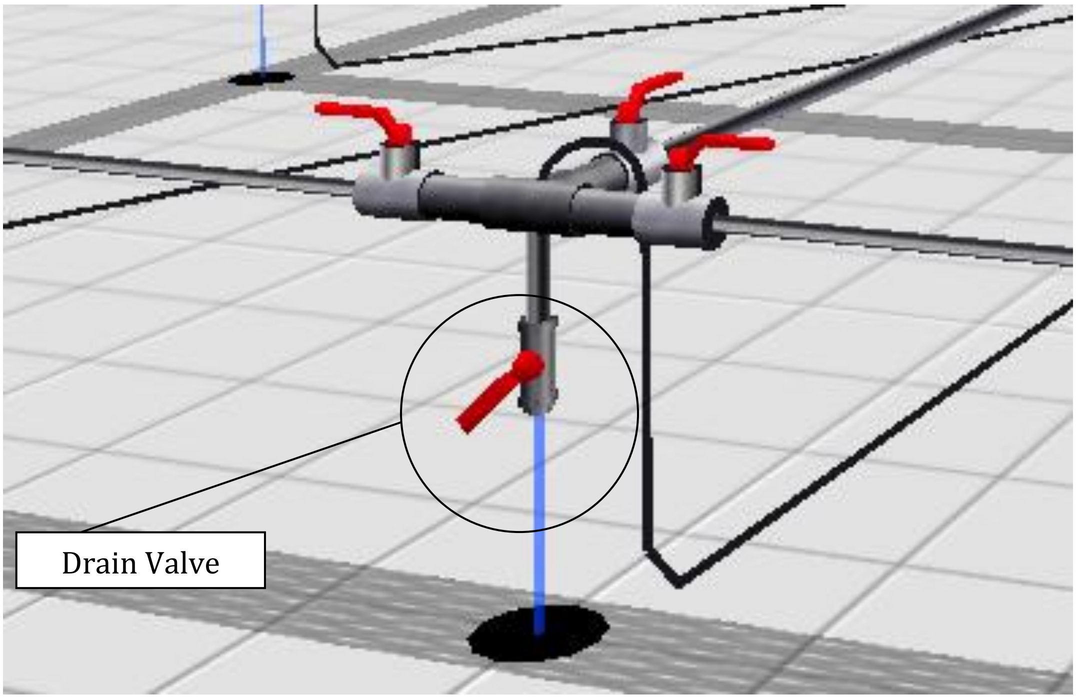

Figure 7 – Image of an Open Drain Valve

Water is taken through nodes 1 through 9. The piezometric line is constructed according to the readings of the piezometers located on the stand (Figure 8).

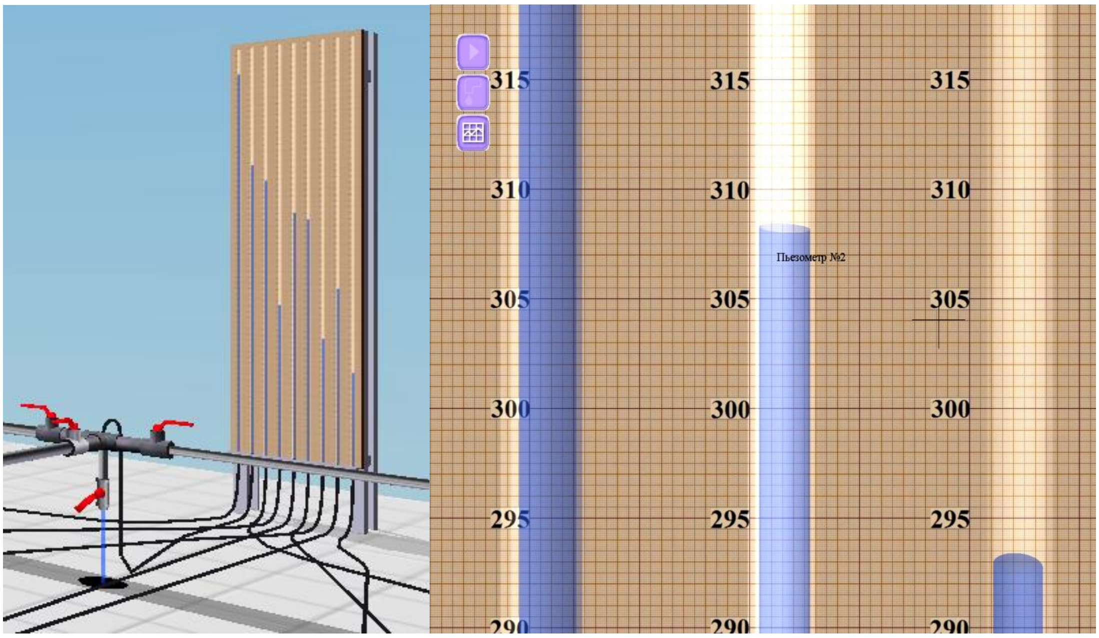

Figure 8 – Image of a Stand with Piezometers

The numerical values of the head in the nodes are applied to the sweep of the piezometers. The direction of movement of water flows in the network lines is determined by the difference in the readings of the piezometers and is applied to the network diagram with colored pencils or ink. Determination of linear water flow rates and verification of the balance of nodal flow rates is carried out analytically.

Based on the piezometer readings, head losses are calculated on individual sections of the network, and then linear water flow rates are determined from the formula:

$$q_{ij} = \sqrt{\frac{h_{ij}}{s}}$$

where h_{ij} – head loss on the network section, m; s – the resistance of the network section (the numerical values of the resistances of the water supply network sections are determined by calculation).

We recommend using tables 1 and 2 to record measurement results.

Table 1 – The Parameters of Water Supply Network in the Nodes

Node	Node Height Z_i, m	Hydrostatic Head (Reading of Piezometer) H_i, m	Free Head at the Node	To Determine the Nodal Flow Rate		
				Volume, L	Filling Time, s	Nodal Flow Rate Q_i, L/s
1	2	3	4	5	6	7
1						
2						
3						
4						
5						
6						
7						
8						
9						

Table 2 – Parameters of the Water Supply Network by Section (Dead End Network)

Section №	Length, m	Section Flow q_{ij}, m	Nominal Diam., m	Calculated Values			Experienced losses on the Section, m	Δh, m	%
				Calc. Diam., m	1000i	Losses on the Section h_{ij}, м			
1	2	3	4	5	6	7	8	9	10
12									
25									
36									
45									
56									
58									
78									
89									

Note: i – the resistivity of the network section (numerical values are determined by the tables depending on the material, pipe diameter and travel flow rate).

LABORATORY WORK №2
«Ring Water Supply Network (4 Rings)»

2.1. General Information

Ring water supply networks are widely used in water supply systems of settlements and industrial enterprises, where it is necessary to ensure uninterrupted water supply to consumers. In any ring water supply network, the following equalities hold: water flows in each node $\Sigma q_{+} = \Sigma q_{-}$; head loss in each ring $\Sigma h_{+} = \Sigma h_{-}$, where: Σq_{+} – water flow suitable to the node; Σq_{-} – water outgoing from the node; Σh_{+} – head loss in parts of the ring with a clockwise movement of water; Σh_{-} – head loss in sections of the ring with the movement of water counterclockwise.

2.2. Purpose of Work

Investigate the operation of the ring water supply network, resulting in:

– build a piezometric line on the expanded profile of the network and determine the direction of movement of water flows in individual areas with unilateral and bilateral power supply of the network;

– determine in an analytical way the linear flow rates of water;

– check the balance of water inflow and outflow in nodes.

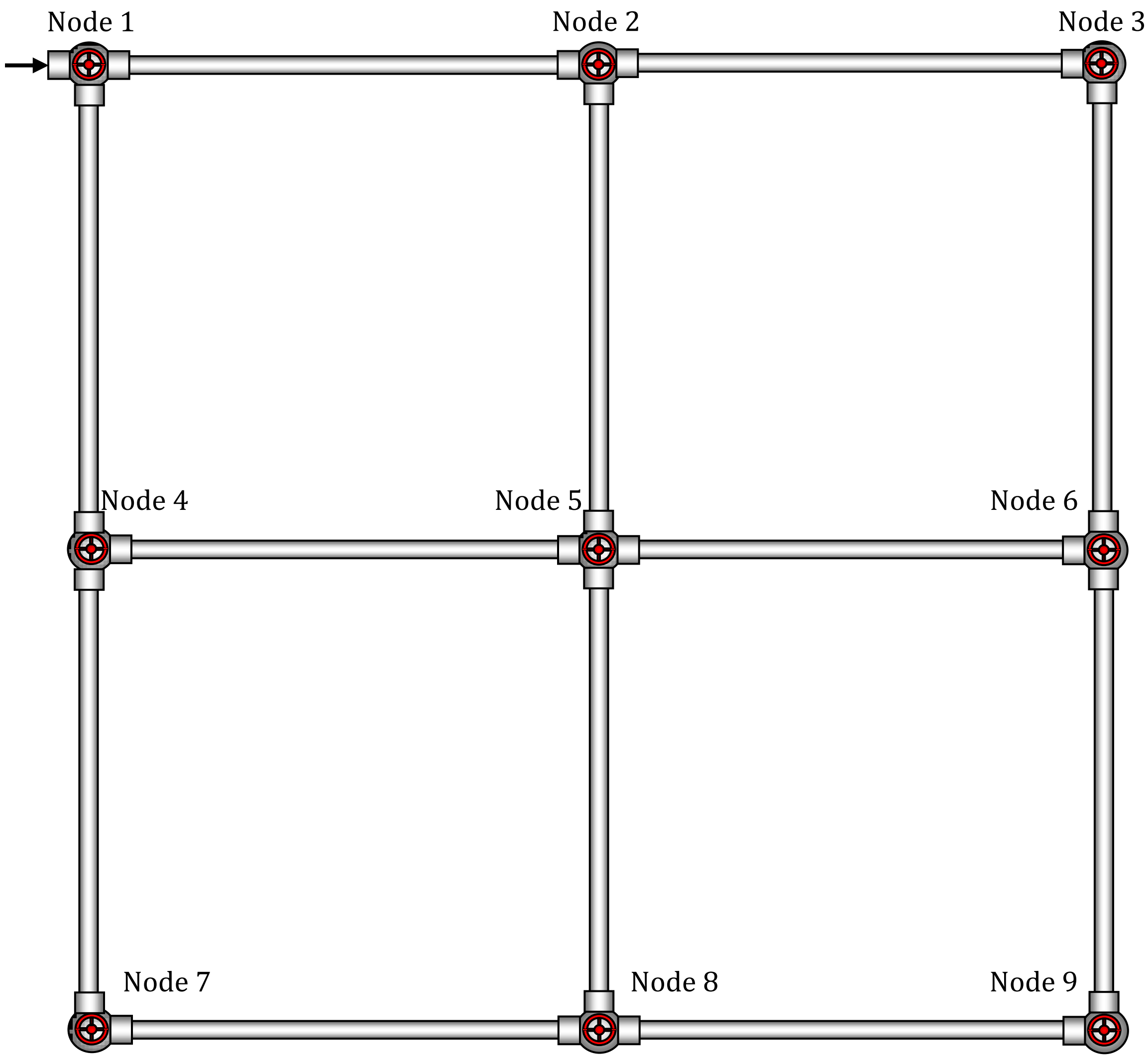

Figure 9 – Scheme of the Ring Water Supply Network (4 Rings)

2.3. Equipment Description

Laboratory work is carried out on a model of a ring water supply network made of metal tubes with a diameter of 10, 15 and 20 mm, depending on the model file. In the course of laboratory work, it is required to determine the parameters similarly to laboratory work №1 (see paragraph 1.3). Figure 9 shows a diagram of a ring water supply network in plan.

2.4. Lab Work Order

By analogy with laboratory work №1, a piezometric line is constructed and the directions of water movement in individual sections of the network are determined. For this purpose, it is necessary to open all flow valves 1, 3, 5 and 6 to pass water through the network lines. Water is drawn through nodes 1 through 9. The piezometric line is plotted according to the readings of the piezometers, and the numerical values of the head in the nodes are plotted on the sweep of the piezometers. The direction of movement of water flows in the lines of the network is determined by the difference in the readings of the piezometers and is applied to the network diagram with colored pencils. The analytical method determines the linear flow of water, and checks the balance of nodal costs. To record the measurement results, it is recommended to use tables 1 and 3.

Table 3 – Parameters of the Water Supply Network by Section (4 Rings Network)

Section №	Length, m	Section Flow q_{ij}, m	Nominal Diam., m	Calculated Values			Experienced losses on the Section, m	Δh, m	%
				Calc. Diam., m	1000i	Losses on the Section h_{ij}, м			
1	2	3	4	5	6	7	8	9	10
12									
23									
14									
25									
36									
45									
56									
47									
58									
69									
78									
89									

LABORATORY WORK №3
«Ring Water Supply Network (2 Rings)»

3.1. Equipment Description

The principle of the laboratory setup is similar to laboratory work 1-2. Figure 10 shows a scheme of a double-ring water supply network in plan.

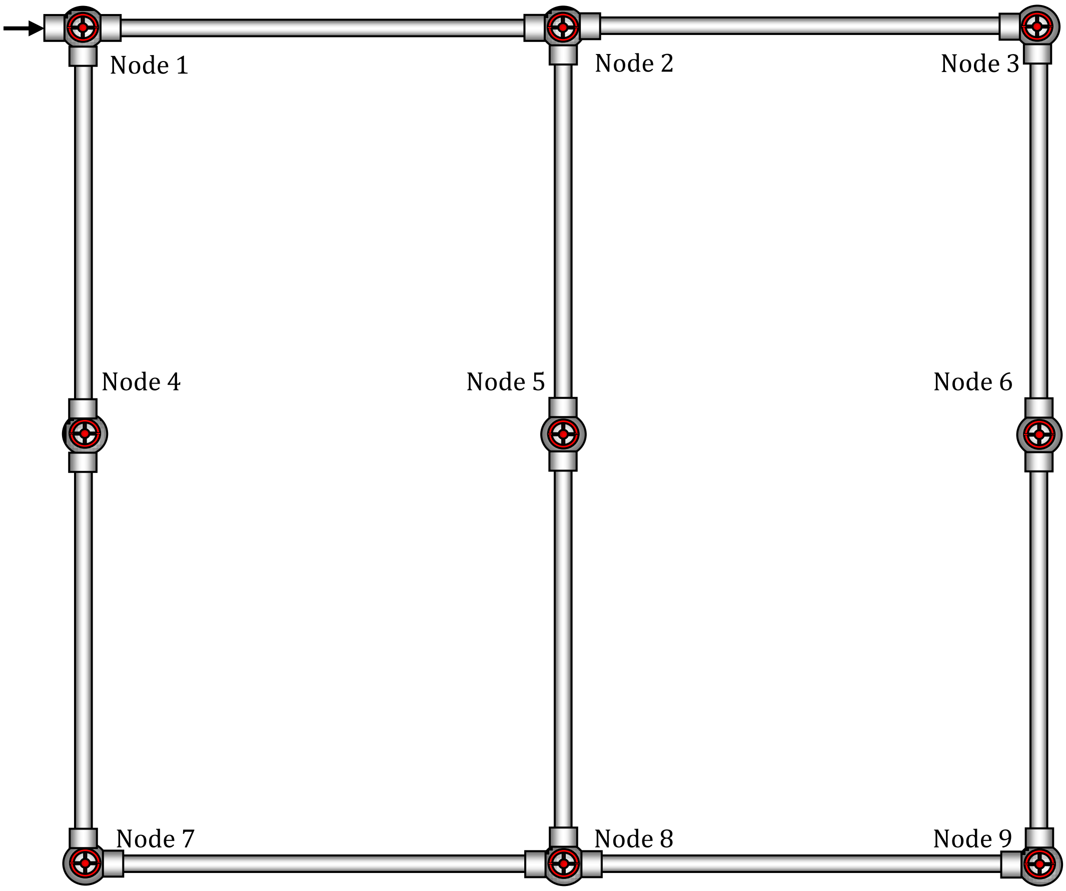

Figure 10 – Scheme of the Ring Water Supply Network (2 Rings)

3.2. Work Order

By analogy with laboratory work 1-2, a piezometric line is constructed and the direction of water movement in individual sections of the network is determined. To record the measurement results, it is recommended to use tables 1 and 4.

Table 4 – Parameters of the Water Supply Network by Section (2 Rings Network)

Section №	Length, m	Section Flow q_{ij}, m	Nominal Diam., m	Calculated Values			Exper. losses on Section, m	Δh, m	%
				Calc. Diam., m	1000i	Losses on the Section h_{ij}, м			
1	2	3	4	5	6	7	8	9	10
12									
23									
14									
25									
36									
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58									
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LABORATORY WORK №4
«Combined Water Supply Network»

4.1. Equipment Description

The principle of the laboratory setup is similar to laboratory work 1-3. Figure 11 shows a scheme of a combined water supply network in plan.

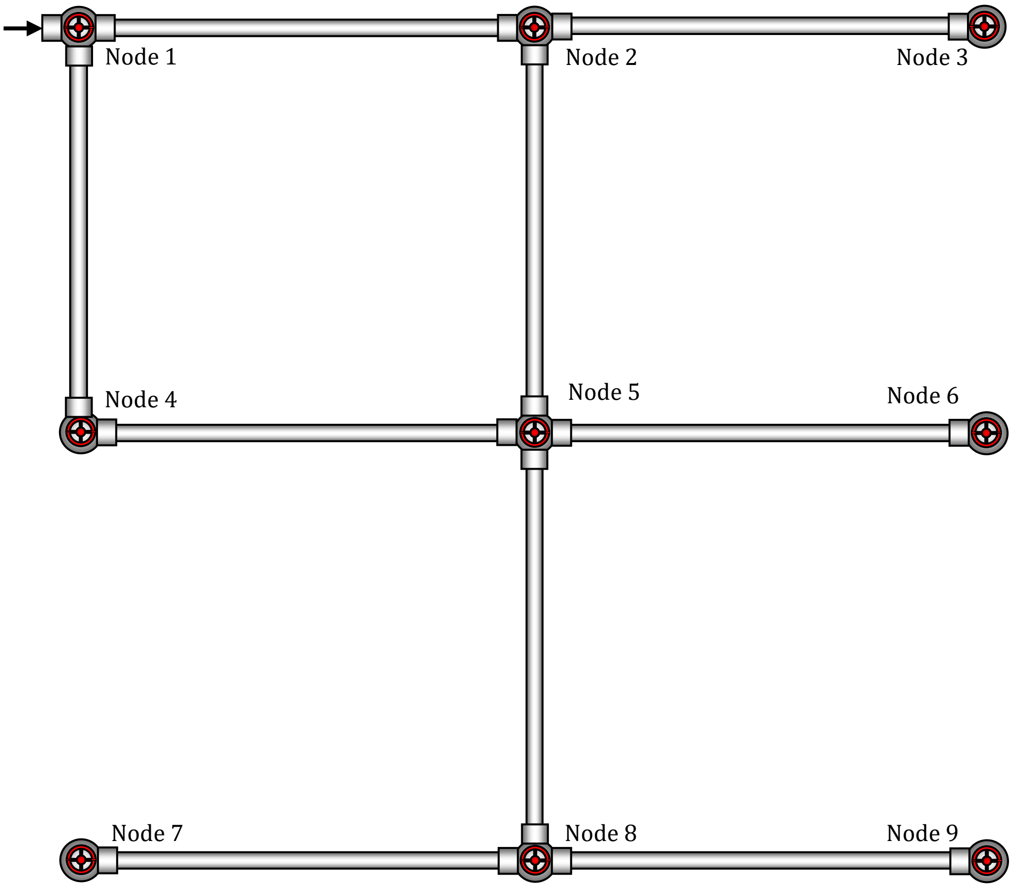

Figure 11 – Scheme of the Combined Water Supply Network

4.2. Work Order

By analogy with laboratory work 1-3, a piezometric line is constructed, and the directions of water movement in individual sections of the network are determined. To record the measurement results, it is recommended to use tables 1 and 5.

Table 5 – Parameters of the Water Supply Network by Section (Combined Network)

Section №	Length, m	Section Flow q_{ij}, m	Nominal Diam., m	Calculated Values			Exper. losses on Section, m	Δh, m	%
				Calc. Diam., m	1000i	Losses on the Section h_{ij}, м			
1	2	3	4	5	6	7	8	9	10
12									
23									
14									
25									
45									
56									
58									
78									
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