

Introduction

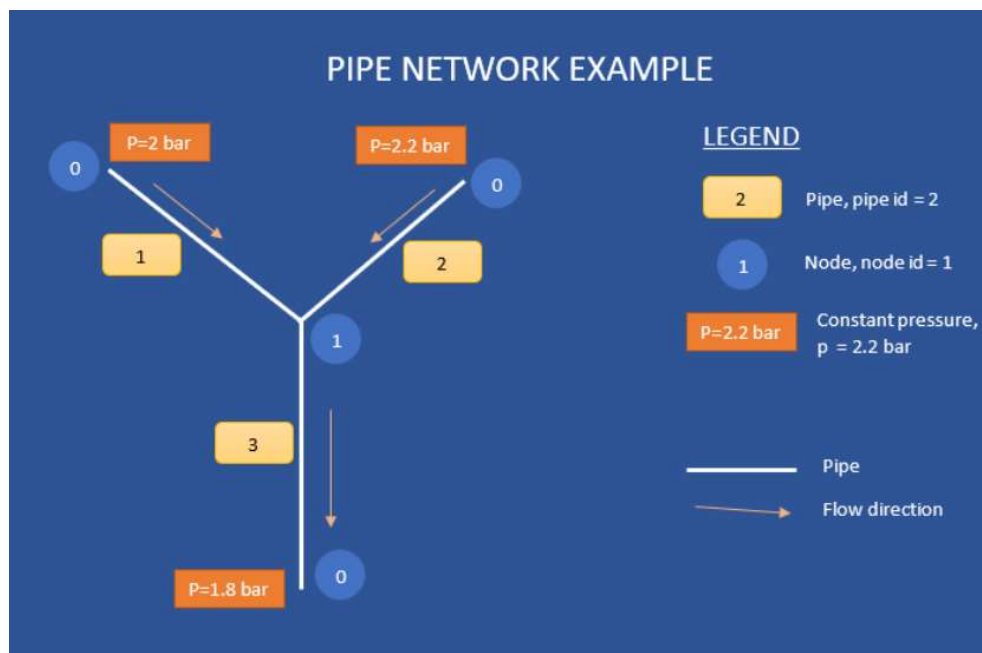
This calculator is still in the early stages of its life and still needs more features that would facilitate and improve its use. On the other hand, the obtained calculation results are reliable, and its function itself is very powerful, as it can provide results for very complicated pipe networks.

It is necessary to study this instruction in detail in order to use the calculator correctly from the first day and to make full use of its possibilities.

Calculation of pipe networks

The pipe network consists of many pipes interconnected in nodes. Tanks, pumps and branches of the pipeline from which or into which the fluid flows or outflows can appear within the pipe network.

Solving the problem of the pipe network implies the calculation of the flow of fluid (q) through individual pipes, and in connection with that the calculation of pressure drops (Δp) through individual pipes, as well as the calculation of pressure in individual nodes.



The above picture shows the simplest example of a pipe network consisting of only three pipes and one node.

In the example shown, it is necessary to determine the flows through individual pipes, for the set values of pressure at their ends, with the known characteristics of the pipes and the fluid flowing through them.

The calculation of such a pipe network requires an iterative procedure, since the pressure in the pipe network node where all three pipes are connected is unknown, and which is marked with the number 1. The flows through individual pipes depend on the pressure in that node.

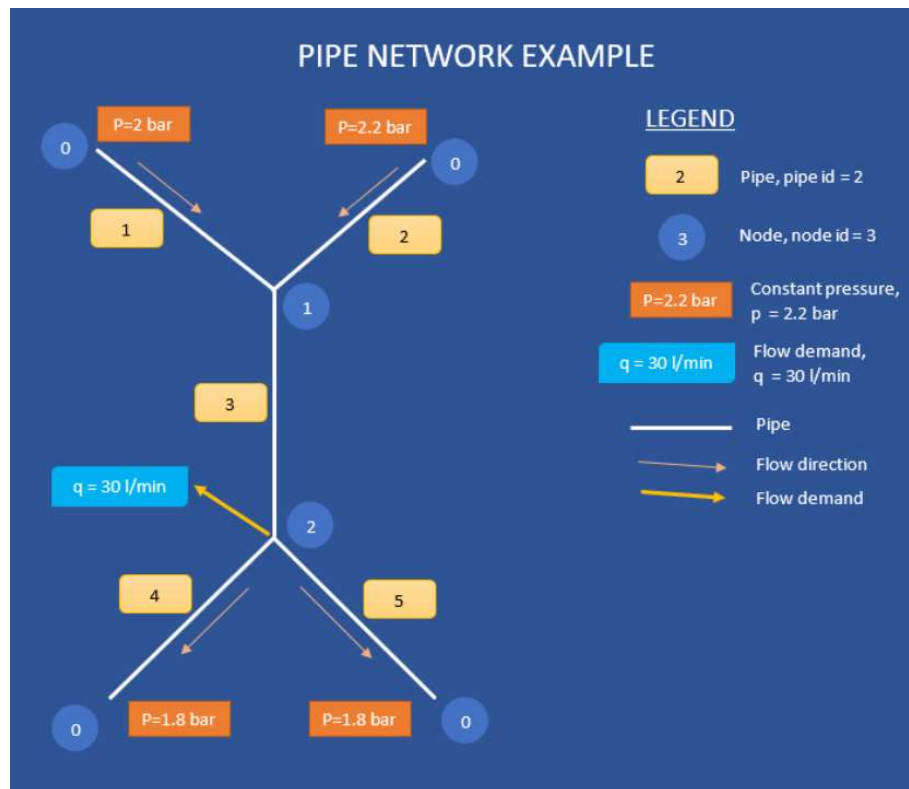
Basic terms

- Nodes are places where two or more pipes join
- Each pipe has its own characteristics - inner diameter, length, roughness of the inner surface, shape (rectangular or circular)
- Pressure in individual nodes is assumed to be overpressure (pressure gauge) $p_m = p - p_{atm}$
- Node designation id, in case of tank, pump or open atmosphere is reserved with designation 0 ($N_1=0$). For such a pipe, it is necessary to enter the pressure value in that node.

Node method

The method used in the online calculator is the node method. The node method is used to calculate the flow and pressures in pipe networks, using the fact that the total flow when observing one node in the pipe network is equal to 0, i.e., that the fluid flow through all pipes connected in one node is equal to 0, so the sum of the flows flowing into a particular node is equal to the sum of the flows flowing from that node.

During the calculation, all nodes are subject to calculation, one after the other, i.e., flows through each pipe connected to a certain node are calculated and thus through a number of iterations a final solution is reached, which satisfies the flow condition through a given node.



In the example shown in the picture, there are 2 nodes in which three pipes are connected. These nodes are labeled $N_1 = 1$, and $N_2 = 2$ (labeled blue). The pipes that are connected in node 1 are marked with numbers 1, 2 and 3 (mark in the yellow rectangle). The pipes that are connected in node 2 are marked with numbers 3, 4 and 5, and from node 2 an additional 30 liters / min of constant flow flows out.

As said, the node method is based on the fact that the total fluid flow in and out of the node is 0. In this example, the total flow through pipes 1 and 2 is equal to the flow through pipe 3, which is a condition for node 1. At the same time, the flow through pipe 3 equal to the total flow through pipes 4 and 5, plus an additional constant flow of 30 liters / min, which is a condition for node 2.

Required data for the calculation

For the calculation of the pipe network by the method of nodes, it is necessary to enter basic data about the pipe network itself, as well as the physical properties of the fluid flowing through the pipe network.

The following data must be entered for each pipe from the pipe network:

- id of pipe (P_{id}) (number 1, 2, 3, ...)

- nodes that this pipe connects, as the id of node N_1 and N_2 (number 1,2,3, ...)
- pipe length L (m or ft)
- inner tube diameter d (mm or inch)
- roughness of the inner surface of the pipe k_r (mm or inch)
- possible local resistance on the pipe due to installed fittings or valves (K)
- if the pipe is connected to a node in which constant pressure is assumed, i.e., if one of the nodes is marked 0, it is necessary to enter this value of pressure ($p [N = 0]$)

Pipe id (P id)	Pipe length (L)
1	1000.0 m
Connecting node one (N 1)	Pipe internal diameter (d)
1	100.0 mm
Connecting node two (N 2)	Pipe surface roughness (k_r)
2	0.01 mm
Constant pressure at 0 node ($p[N=0]$)	Local resistance (K)
0 bar	2

Pipe data entry form - must be entered in order - Pipe id, Node id 1, Node id 2, Constant pressure p (only if node id = 0), pipe length L , pipe internal diameter d , pipe internal surface roughness k_r , local resistance (if any) K .

The following data must be entered for each node in the pipeline:

- node id (number 1,2,3, ...)
- the flow of fluid that flows out of that node or that flows into that node - q
- assumed value of pressure in the node - p

Node id (N id)
1
Flow from node (q)
25 l/min
Pressure in node (p)
2.2 bar

Form for entering the characteristics of nodes in the pipe network - in order it is necessary to enter the node id, the flow from node q , the assumed pressure in node p

Important: The default pressure value in node (p) is mandatory and cannot remain 0. For each node, the user should enter a default pressure value which can be any expected value, i.e., a value that is

between known pressures at pipeline endpoints as which are tanks, pumps or openings to the atmosphere. In the specific case, the assumed value of the pressure in the node $p = 2.2$ bar is shown.

After the calculation is completed, the actual calculated pressure in each node is shown in the results table.

Fluid characteristics

For the calculation of the pipe network, it is necessary to enter the values of at least two physical properties of the fluid - density ρ and viscosity ν .

Fluid density (ρ)		Dynamic viscosity (μ)	
998.0	kg/m ³ ▼	0.001	Pas ▼

Fluid data entry form - it is necessary to enter fluid density ρ and fluid viscosity ν . It is also possible to select a fluid from the list of available fluids.

Piping connected to the tank

If the pipe is connected to a tank (one or more), a pump, or is open to the atmosphere and the pressure is constant at that point, then the id of the node connecting the pipe is entered value 0, or $N_1 = 0$, and at the same time enters the value of that constant pressure $p = 10$ m H₂O (bar or psi).

Pipe id (P id)	
2	
Connecting node one (N 1)	
0	
Connecting node two (N 2)	
2	
Constant pressure at 0 node ($p[N=0]$)	
10	m H ₂ O ▼

*Example of inlet pipe $P_{id} = 2$ connected to a tank that is at 10 m above sea level.
The tank is marked 0 as the node id*

In this way, it is possible to enter the value of the pressure that occurs as a consequence of the height difference of the pipeline as data in the pipe network. Namely, if the pipe is connected to a tank located at an altitude that is higher than the altitude at another end of the pipe network, it is possible to enter this data as the pressure in the node by marking the node with $N_1 = 0$, and the difference in altitude as the pressure in that node, e.g., $p = 10$ m H₂O (if the difference in altitude is equal to 10 m).

Additionally, if the tank itself is under a certain overpressure, then it is necessary to add this value to the pressure due to the difference in altitude. If the overpressure in the tank is 20 m, the total value of pressure in N_1 is $10\text{m} + 20\text{m} = 30\text{m}$.

Pipe id (P id)	
2	
Connecting node one (N 1)	
0	
Connecting node two (N 2)	
2	
Constant pressure at 0 node (p[N=0])	
30	m H ₂ O

An example of a pipe connection connected to a tank that is at 10 m above sea level, and the tank itself is under an overpressure of 20 m, which is a total of 30 m of water column. The tank is marked 0 as the node id

Piping connected to the pump

If a pump is created on one side of the pipeline that creates a pressure of a certain value, in that case, as with the pipeline connected to the tank, the id of the node connecting that pipe is entered, the value 0, ie $N_1 = 0$, pressure p (bar or psi). In this way, it is possible to enter the value of the pressure produced by the pump as data in the pipe network.

Pipe id (P id)	
3	
Connecting node one (N 1)	
0	
Connecting node two (N 2)	
2	
Constant pressure at 0 node (p[N=0])	
4	bar

Example of a pipe connection connected to a pump that gives a pressure of 4 bar at the pump outlet, The pump is marked 0 as the node id

Pipeline connected to the open atmosphere

If the pipe is open to the atmosphere on one side, you need the id of the node that connects that pipe to enter the value 0, ie $N_1 = 0$, and at the same time enter the value of constant pressure $p = 0$ (if for other nodes are entered overpressures - pressure gauges).

Pipe id (P id)
1

Connecting node one (N 1)
0

Connecting node two (N 2)
1

Constant pressure at 0 node (p[N=0])
0.0 bar

Example of the inlet of a pipe that is open to the atmosphere at one end, The opening to the atmosphere is marked 0 as the node id, and the pressure value is 0

Prerequisite for pipe network calculation

For the calculation of the pipe network, it is obligatory to know the value of pressure in at least two nodes. These two nodes of the pipe network can be combinations of one or more tanks, with an opening to the atmosphere, the existence of pumps with two known pressures - in front and behind the pump (inlet and outlet).

In order for the calculation of the pipe network to be possible, it is necessary to recognize and mark at least two nodes with known pressure on the pipe network with $N_1 = 0$. This means that each pipe network must have at least two points, i.e., two nodes where the pressures are known. Between such two points (nodes), fluid flow is established with certain flows through all pipes, depending on the shape and dimensions of the pipe in the pipe network.

At the same time, this means that a certain amount of fluid flows through the pipe network, which is determined by the pressure difference between at least two nodes that are with known and constant pressures and are marked with $N_1 = 0$.

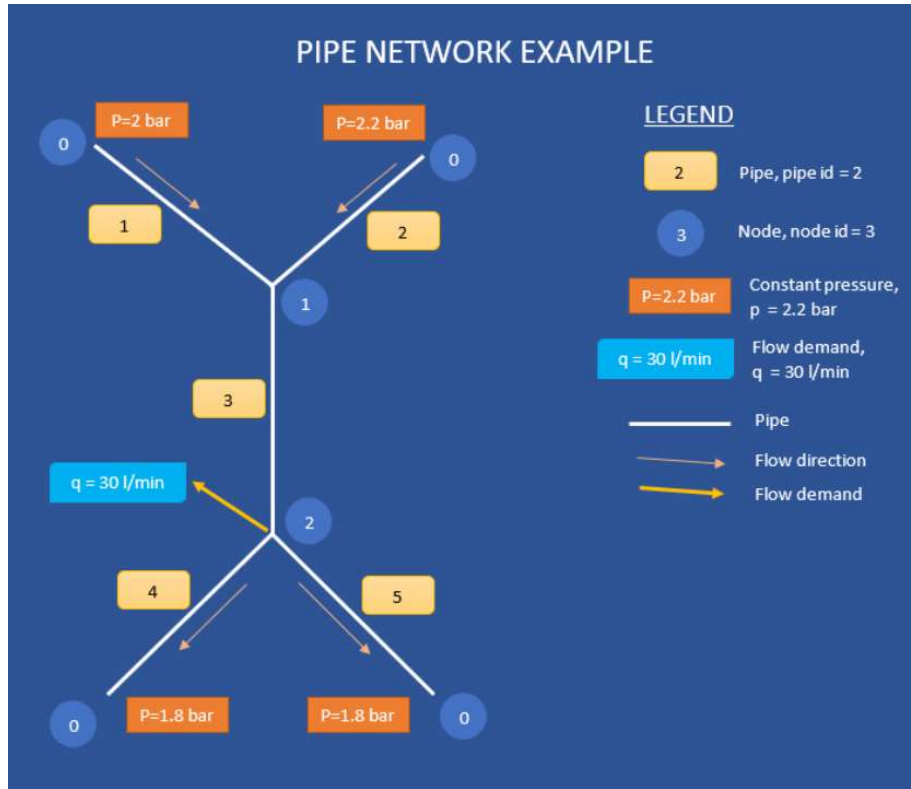
Use of pipe network calculation software

The solution of one example of a pipe network calculation is presented below. The same example can be seen on the calculator itself. To view this example, click the "develop network 2" button to load the example. Within the example, you can see a sketch of the pipe network, as well as a table with all the data that need to be entered for the pipe network.

Pipe network description

The pipe network consists of 5 pipes connected in two nodes. Pipes are numbered 1-5, and nodes are numbered 1-2.

The pipe network connects a total of 4 tanks with constant pressures - different altitudes.



Sketch of a pipe network - examples that we will solve with the help of a calculator - network no. 2

The process of solving the pipe network begins with entering data for each individual pipe. After entering the data for all pipes, it is necessary to enter all the data for each node (except the node marked 0).

The data for the pipe is entered in the form entitled "PIPES TABLE - Create / Edit pipe". Node data is entered in a form titled "NODES TABLE - Create / Edit node".

After entering the data for the pipe/node, it is necessary to click on the add pipe / add node button and thus the entered data will be saved in the table "The network calculation results". This table shows the data for the pipes and for all the nodes entered by the user.

List of pipes											List of nodes		
ID	N1	N2	p[N=0] [bar]	L [m]	D [mm]	kr [mm]	K	q [l/min]	v [m/s]	Id	q [l/min]	p [bar]	
1	0	1	2.0	500.0	100.0	0.1	0.0	0.0	0.0	1	0.0	1.9	
2	0	1	2.2	500.0	100.0	0.1	0.0	0.0	0.0	2	30.0	1.85	
3	1	2	0.0	1000.0	200.0	0.1	0.0	0.0	0.0				
4	2	0	1.8	500.0	100.0	0.1	0.0	0.0	0.0				
5	2	0	1.8	500.0	100.0	0.1	0.0	0.0	0.0				

Network calculation results table

If necessary, the pipe or node that was entered incorrectly "remove pipe / remove node" can be deleted from the table, and it is possible to delete the complete content "remove all".

After all the data has been entered in accordance with the layout of the pipe network, by clicking on the Calculate network button the program will start the iterative calculation process and at the end show the solutions in the columns flow - q flow rate - in the table "list of pipes", node p table "list of nodes".

The network calculation results Export results .xlsx

Remove pipe Deselect Remove node

List of pipes

ID	N1	N2	p[N=0] [bar]	L [m]	D [mm]	kr [mm]	K	q [l/min]	v [m/s]
1	0	1	2.0	500.0	100.0	0.1	0.0	131.95	0.28002
2	0	1	2.2	500.0	100.0	0.1	0.0	310.6	0.65912
3	1	2	0.0	1000.0	200.0	0.1	0.0	442.55	0.23478
4	2	0	1.8	500.0	100.0	0.1	0.0	206.28	0.43773
5	2	0	1.8	500.0	100.0	0.1	0.0	206.28	0.43773

List of nodes

Id	q [l/min]	p [bar]
1	0.0	1.9485
2	30.0	1.9171

Remove all nodes

Table "The network calculation results" shows all the entered data, as well as solutions for the calculation of the pipe network - flow q, fluid velocities v in the pipes, pressure in the nodes p

To change the data for one pipe or one node, it is necessary to select the row in the table "The network calculation results" in which the pipe whose data needs to be changed, and then it will be possible in the data entry form to change the data for pipe or node. After the change is completed, it is necessary to click on the Edit pipe / Edit node button and the change will be saved in the table "The network calculation results".

After the calculation is completed, all results can be exported to a special Excel file and saved to local disk. If necessary, this data can be reloaded into the calculator later. It is first necessary to save the Excel file in which the data is saved to the local disk as .csv files. Previously saved data can be imported into the calculator using the "import pipes from .csv" and "import nodes from .csv" buttons.

Conclusion

To the best of my knowledge, this is currently the only online calculator for calculating pipe networks that can be used free of charge. I hope that you will be able to apply the calculator to solve specific tasks in the field of fluid flow through pipe networks.

If necessary, you can contact me for help with setting the data for a specific problem, although I hope that after reading this guide you will be independent in solving it.

Zoran Savović, info@pipeflowcalculations.com

<https://www.pipeflowcalculations.com/network/index.xhtml>