SUNRISE

PIPENET® NEWS

SUMMER 2018

LEADING THE WAY IN FLUID FLOW ANALYSIS

IN THIS ISSUE...

Gastech
EXHIBITION & CONFERENCE

17-20 SEPTEMBER 2018 | BARCELONA | SPAIN

Visit our booth J108 at the leading exhibition and conference for the global gas, LNG and energy industries. We are looking forward to meeting you at Gastech!

**Fira de Barcelona
Gran Via venue
Av. Joan Carles I, 64
08908 L'Hospitalet de Llobregat
Barcelona**

Modelling Valves in PIPENET

It is clear that modelling of items such as valves, control valves, surge relief valves, relief valves, rupture discs and regulators are essential aspects of transient analysis. PIPENET can model all such items. When it comes to valves, the data which is available may be incomplete and often is. PIPENET can model (i) any type of valve from any manufacturer and (ii) even when only partial data about the valve is available.

In this document the following section are available.

       1 – General methods and options for modelling valves.
       2 – How to model control valves.
       3 to 6 – Various pressure regulating devices.

1. Modelling Valves:

Valves are modelled using the following basic equation. We believe that the same equation is probably used in the Russian Federation, but it may be written in a different form. It can be seen that the valve co-efficient Cv depends on the valve position s.

$$P_1 - P_2 = \frac{\rho Q |Q|}{\rho_0 C_{v(s)}^2}$$

There are 4 different ways in which a valve can be modelled depending on what data is available.

1. Full characteristic data for the valve is available:

If the curve of how 'Cv' changes with the valve position 's' is known as a graph or as a table it can be input into PIPENET library. The dialog box for this is shown below.
In this dialog box s = 0 means the valve is fully closed and s+ 1 means the valve is fully open.
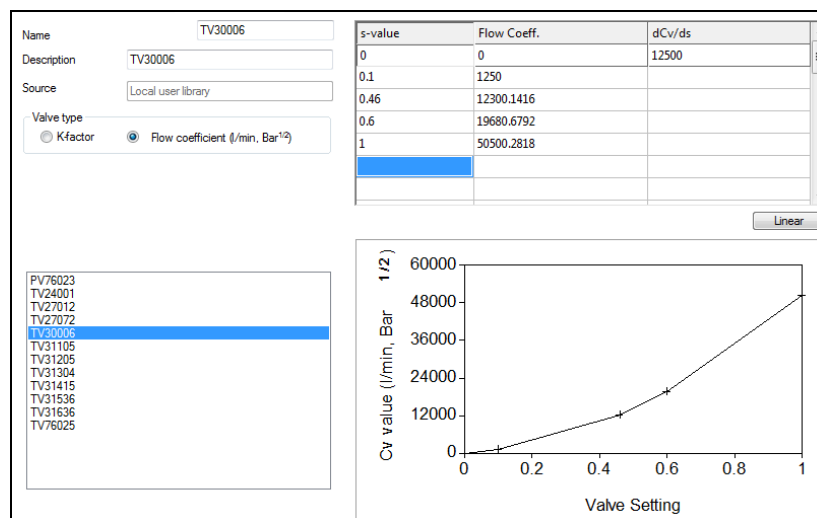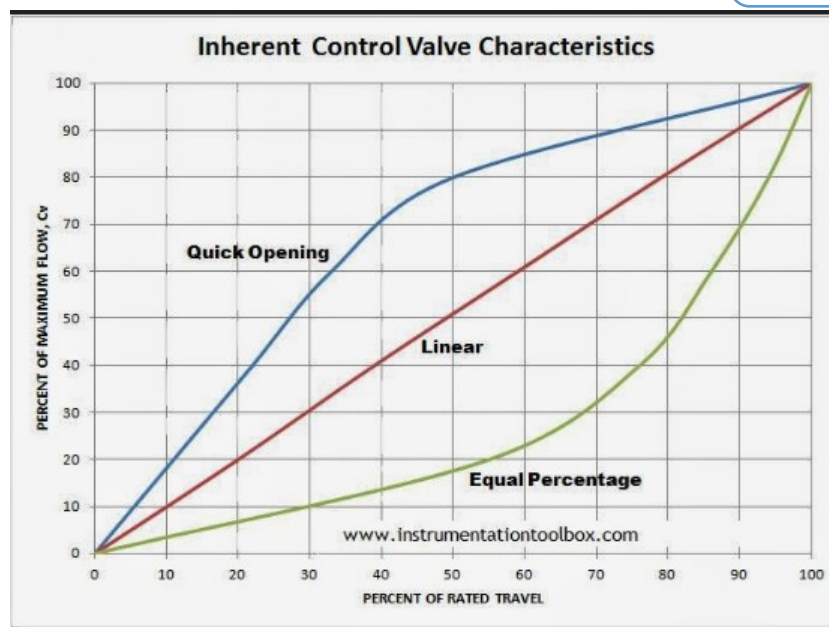

2. Fully open Cv is available:

If the manufacturer can only provide the Cv when the valve is fully open the following method can be used. The user can specify the Cv when the valve is fully open and select from one of the standard curves.
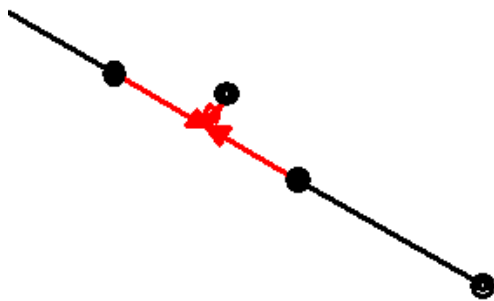
The flow profile is taken from the following graph.


3.   Standard valve types:

If the manufacturer's data for the valve is not available, PIPENET can estimate its characteristics.

Built-in Standard Valve Types

Seven typical valves are available to the user. These can be chosen from gate valve, globe valve, butterfly valve, ball valve, diaphragm valve, angle valve and Y-valve. One or several of the following information is required to calculate the valve k-factor:
 • Inside diameter: insider diameter of upstream pipe.
 • Contraction ratio: ratio of valve seat diameter/area to pipe diameter/area, which must be a value between 0 and 1. The default value is 1.0.
 • Disc shape: flat plate (default) or lenticular, only required for butterfly valve.
 • Disc thickness: valve disc maximum thickness, only required for butterfly valve.
 • Body material: forged (default) or cast-body, only required for angle valve.
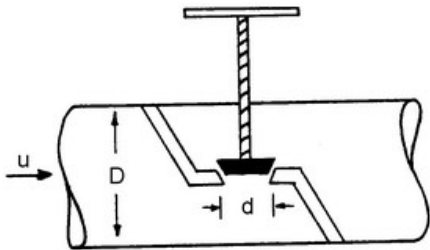 • Stem inclined angle: < 50 degree (default) or > 50 degree, only required for Y-valve.

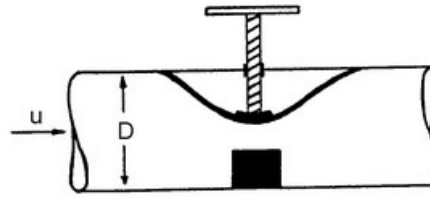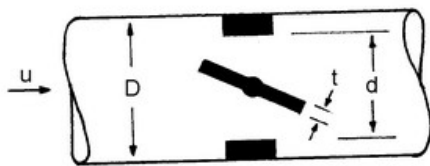PIPENET can estimate the characteristics for the following valve types:
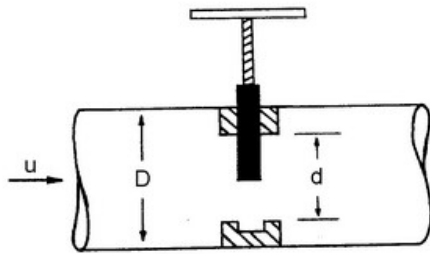
Gate Valve
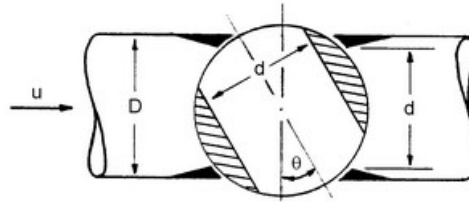
Ball Valve

Globe Valve

Diaphragm Valve

Butterfly Valve
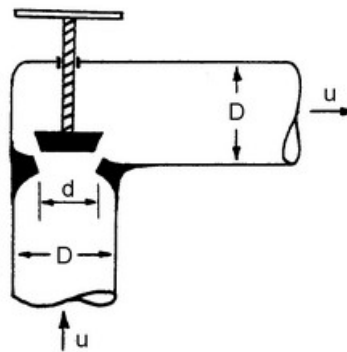
Angle Valve
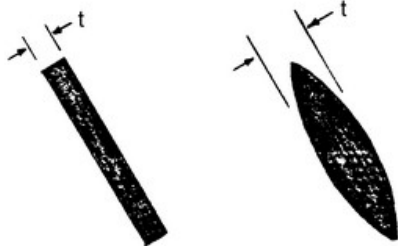
(a) flat plate disc   (b) lenticular disc
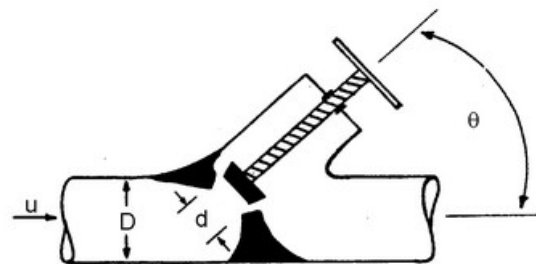
Y-type Valve

4.   Non-Operating Valve:

Non-operating valves are modelling using the following equation. Such valves simply give a pressure loss and do not operate during the simulation. They are modelled by using a fixed k-factor.

$$P = \frac{1}{2} k \rho u^2$$

The value of k can be obtained from one of the following ways.
(i)   Pick it up from the extensive built-in library in PIPENET
(ii)   PIPENET can calculate it given required parameters
(iii)   It can be input by the user

2. Control Valves (Pressure, Flow, Differential Pressure), Control of Variable Speed Pumps:

In the example below we consider the speed control of a variable speed pump. The same principle applies to control valves and other control items. It is possible to use PID control or Cascade control in PIPENET.

Pump Speed Control:
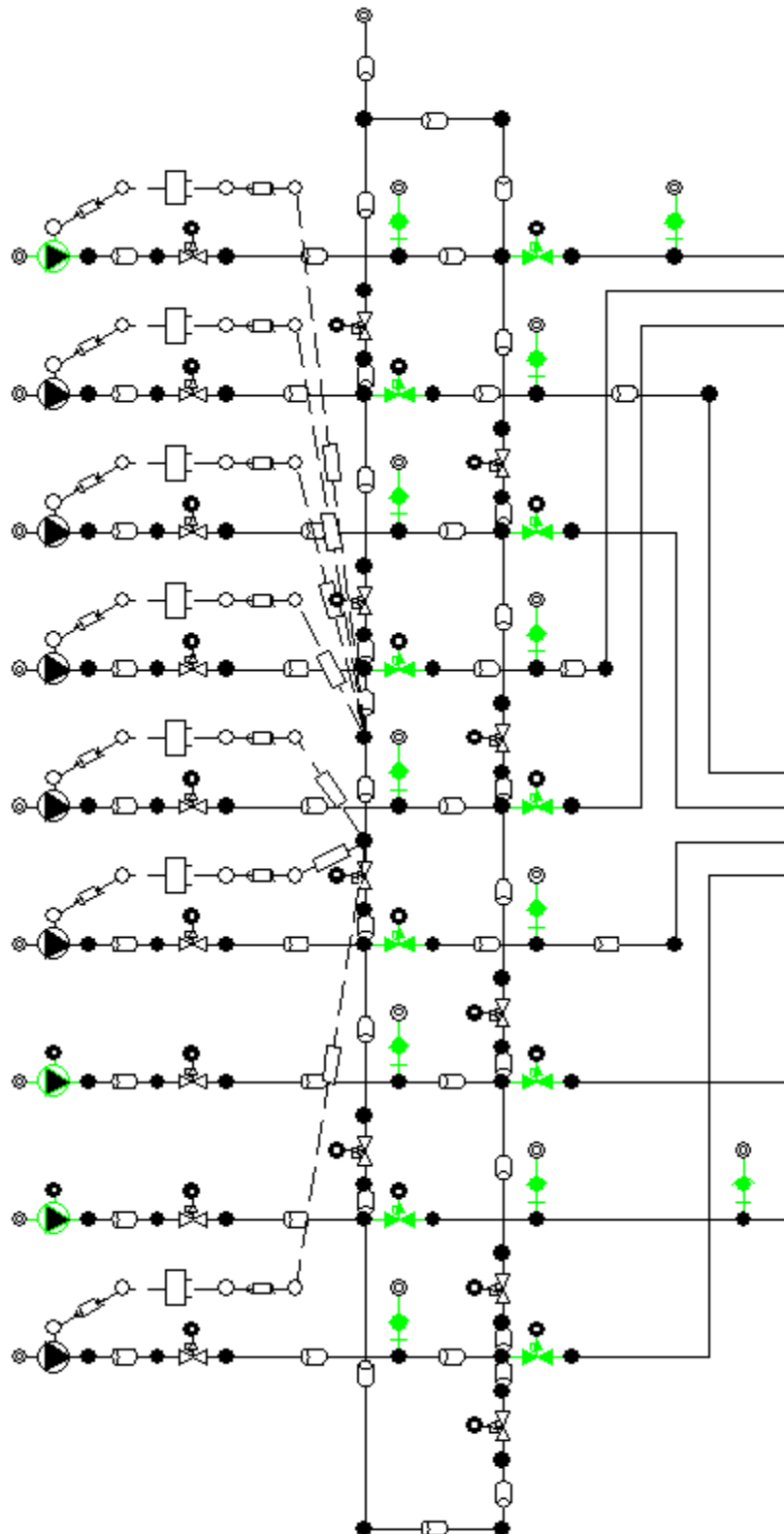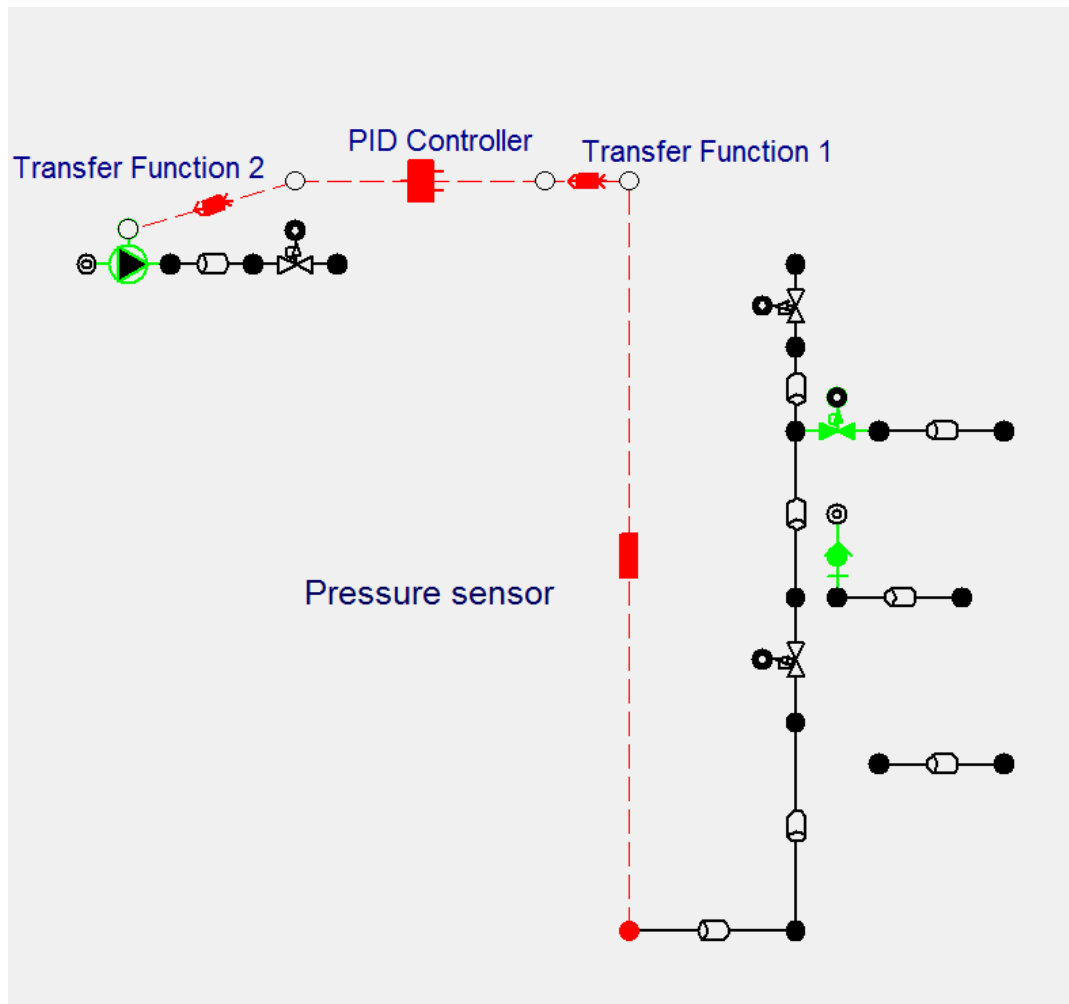
Pressure transients tend to be extremely fast. For this reason the dynamics of items such as the flow transmitter have been taken into account by this user. In particular the following components form part of the control loop.

- A pressure sensor. It is also possible to use pressure or differential pressure sensors.
- A transfer function (specified to be first order) which models the dynamics of the pressure transmitter. In effect the pressure sensor and the transfer function together model the signal from the physical pressure transmitter.
- A PID controller. In this model the user has considered proportional and integral terms.
- A second transfer function which models the dynamics of the control valve. This represents the response of the control valve to the signal it receives from the PID controller.

Flow Control Valve:
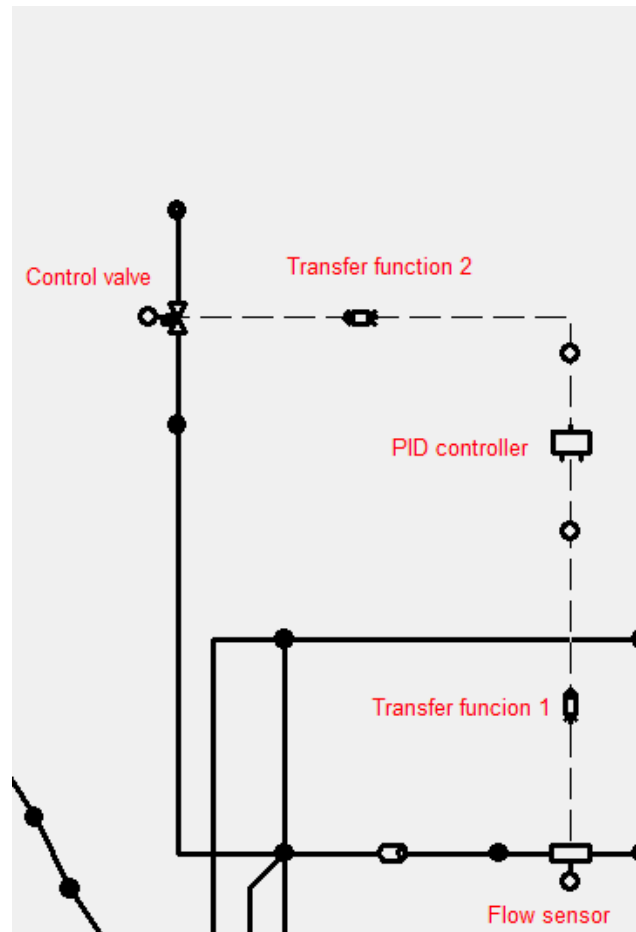
3. Pressure Surge Relief Valve:

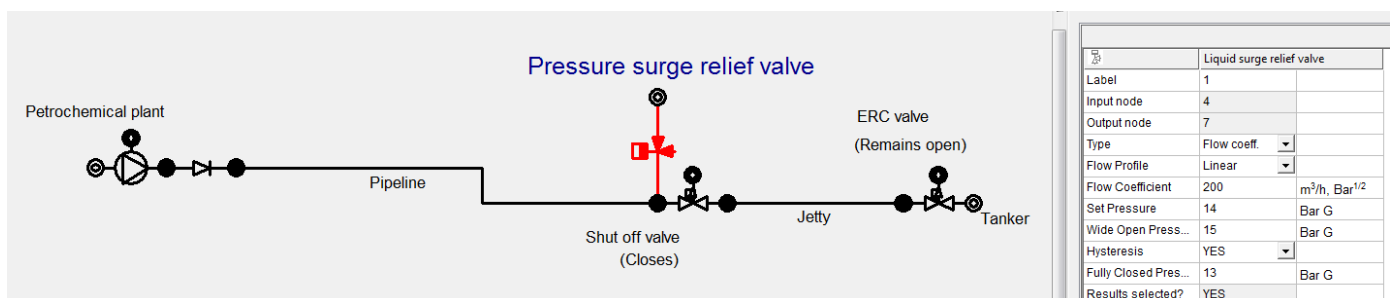When a system experiences transient pressure surge resulting in a high pressure, it is extremely important for the relief valve to respond quickly. Relief valves which respond in this manner are called pressure surge relief valves and are usually assisted by pressurised nitrogen. Such valves are often used in loading/unloading systems which are essential in LNG plants.

An example of a pressure surge relief valve and its data are shown below.

Liquid surge relief valve		
Label	1	
Input node	4	
Output node	7	
Type	Flow coeff.	
Flow Profile	Linear	
Flow Coefficient	200	$m^3/h, Bar^{1/2}$
Set Pressure	14	Bar G
Wide Open Press...	15	Bar G
Hysteresis	YES	
Fully Closed Pres...	13	Bar G
Results selected?	YES	

Surge Relief Valve Cv = 200 (m3/hr, bar)

Surge Relief Valve Cv = 50 (m3/hr, bar)
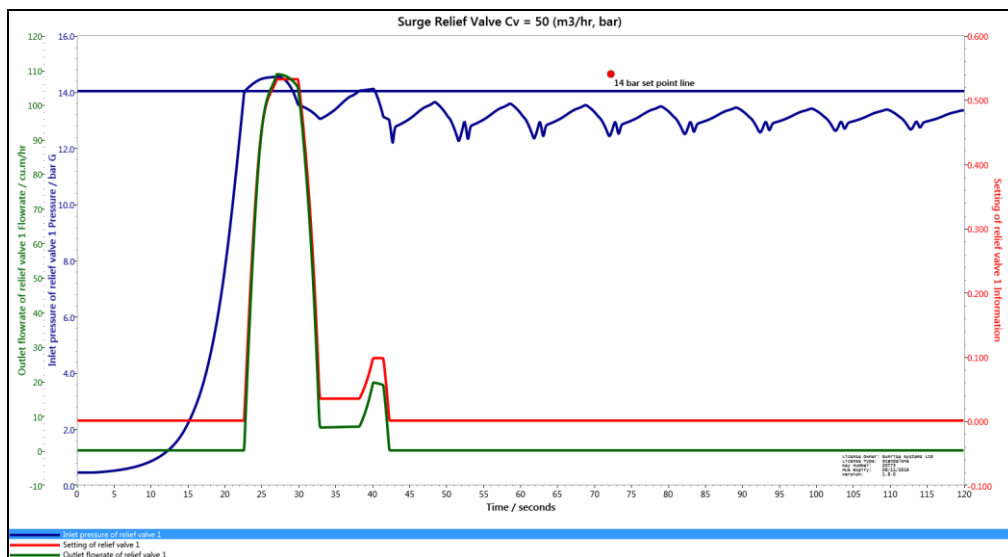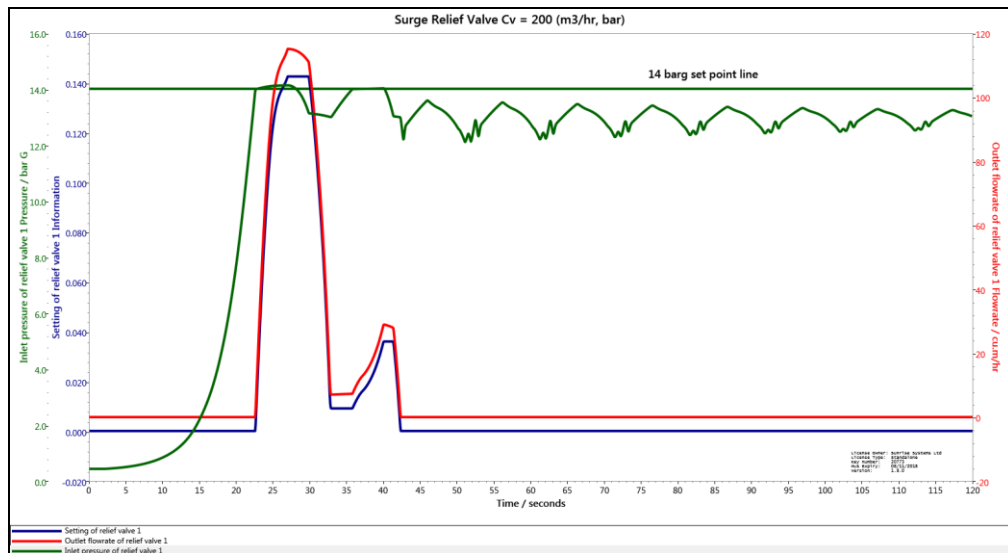
4. Relief Valve:

A relief valve is not a very fast acting valve and so the dynamics of its operation is relevant. For this reason it may not be a good idea to use it as a pressure surge relief valve.

Safety valve		
Label	1	
Input node	4	
Output node	7	
Type	Flow coeff.	
Flow Profile	Linear	
Flow Coefficient	200	m^3/h, $Bar^{1/2}$
Set pressure	14	Bar G
Wide open pressure	15	Bar G
Hysteresis	YES	
Fully closed press...	13	Bar G
Time response or...	First	
Time Constant	2.0	sec
Results selected?	NO	

Relief valve with Cv = 50 (m3/hr, bar), time constant = 5 secs
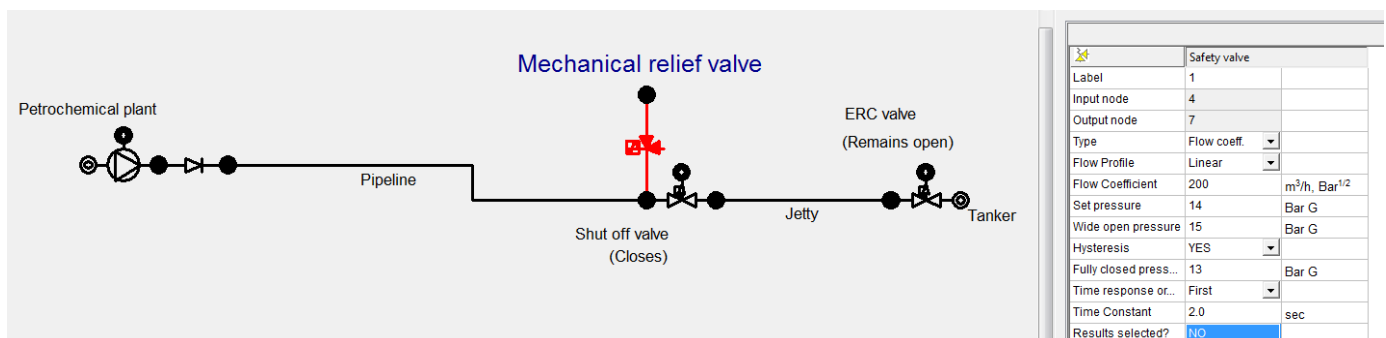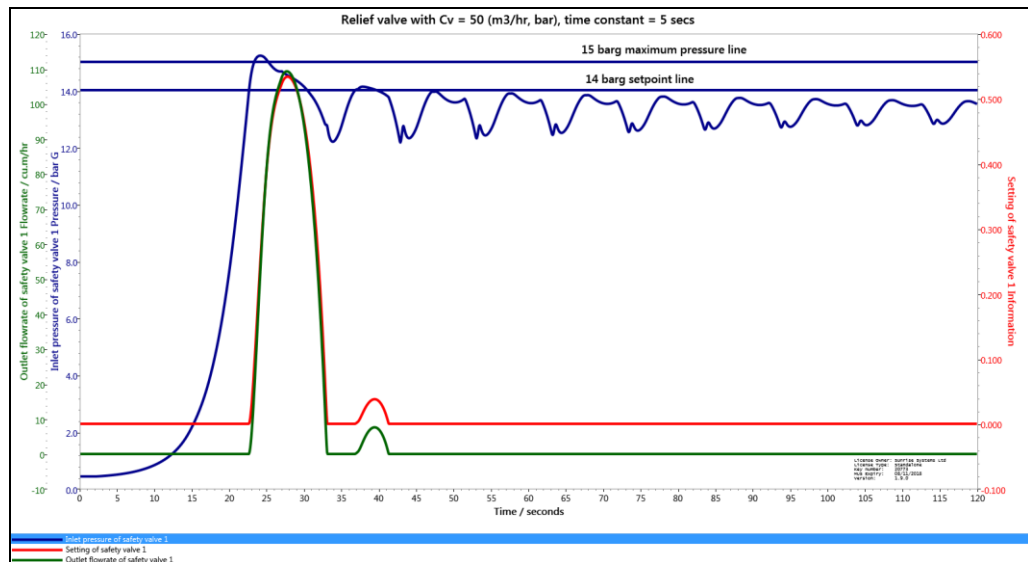
5. Rupture Disc:

This similar to a relief valve except that once it opens it will remain open and will not close again. It is often used because it is cheaper than a relief valve.

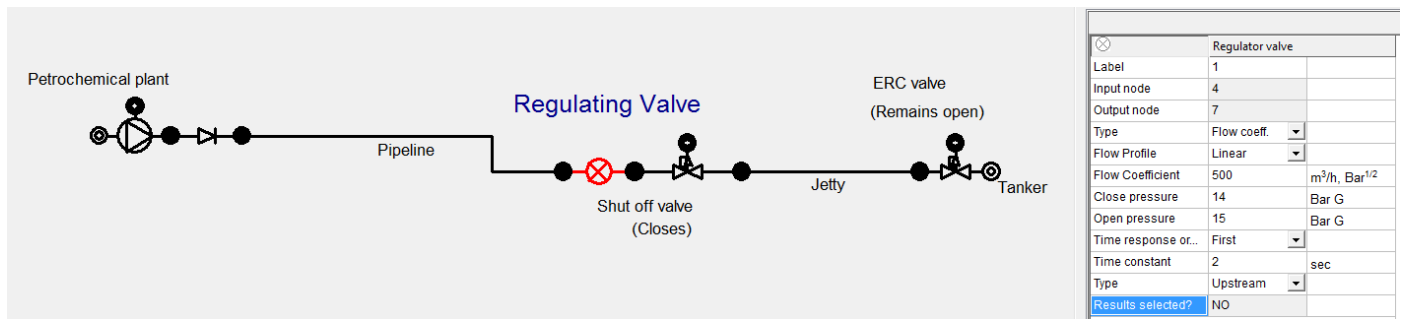| ⓘ	Bursting disc	
Label	1	
Input node	4	
Output node	7	
Type	Flow coeff.	
Flow Profile	Linear	
Flow Coefficient	Unset	$m^3/h, Bar^{1/2}$
Bursting press. diff.	15	Bar
Bursting time	2	sec
Results selected?	NO	

30 mm Diameter Rupture Disc
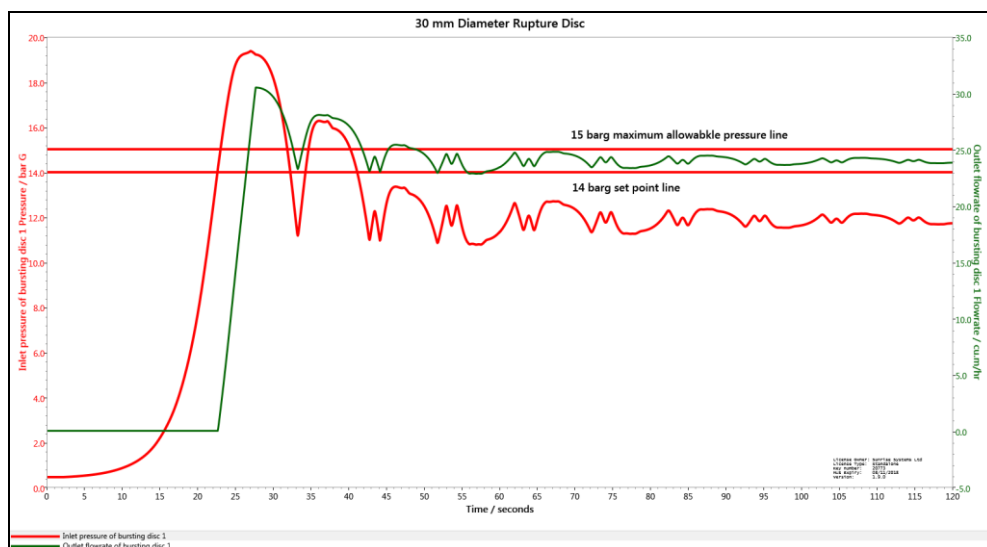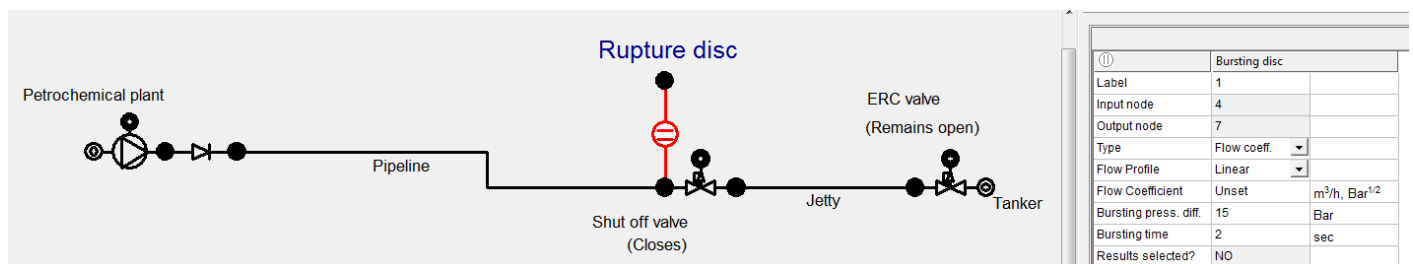
6. Pressure Regulating Valve:

This can be an upstream or downstream pressure regulating valve. As pressure transients are extremely fast the dynamics of a regulating valve needs to be modelled.

Regulator valve		
Label	1	
Input node	4	
Output node	7	
Type	Flow coeff.	
Flow Profile	Linear	
Flow Coefficient	500	m^3/h, Bar$^{1/2}$
Close pressure	14	Bar G
Open pressure	15	Bar G
Time response or...	First	
Time constant	2	sec
Type	Upstream	
Results selected?	NO	

Closing Remarks:

In this document we have shown that PIPENET has a very comprehensive range of models for valves. Virtually every situation in which valves are used can be modelled in PIPENET. Moreover, even if only partial data for a valve is available PIPENET can be used effectively.

Water Injection Systems Capability of PIPENET

PIPENET can be used to model various aspects of water injection systems. This includes establishing potential water hammer problems, cavity formation and collapse, sequence in which booster pumps and water injection pumps should be started, and the calculation of unbalanced force-time history with the view of further processing by pipe stress analysis programs.

Typically, water injection systems are modelled in PIPENET as 2 or 3 parts depending on the user's preference and convenience. The aims of the simulations are often different between the different parts. In the sections below, we show the schematic drawings from PIPENET and some corresponding graphical results. Naturally, if the user prefers, the complete system can be set up as one PIPENET network.

1. Seawater Lift Pump Section up to Deaerator

In this case, seawater lift-pump trip followed by re-start is considered. The lift pumps are submersible pumps. When they trip a cavity forms downstream in the riser pipe because no air release valve has been installed in the riser. When the pumps re-start the cavity collapses leading to a large pressure surge.
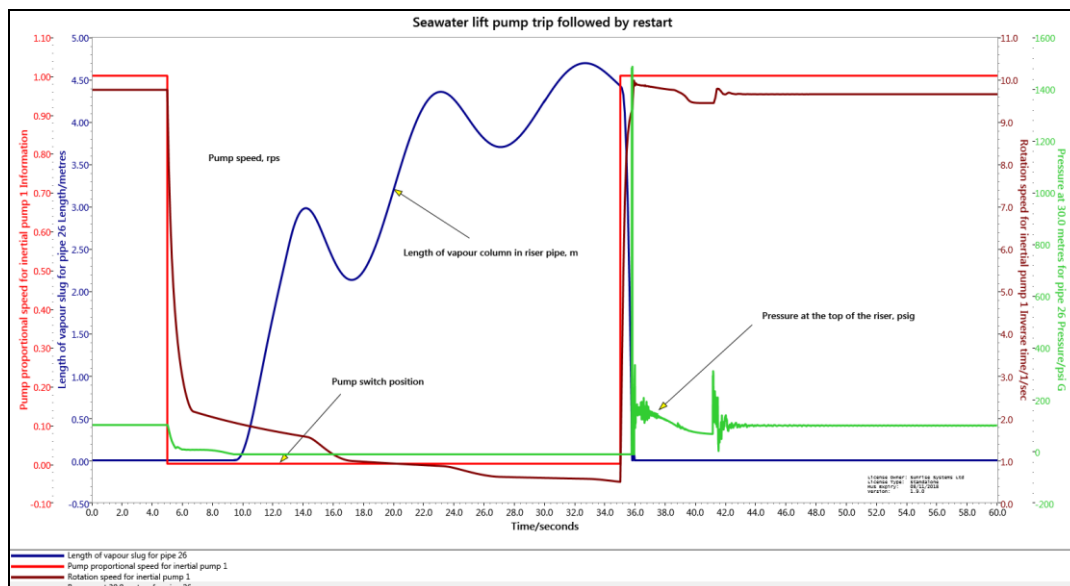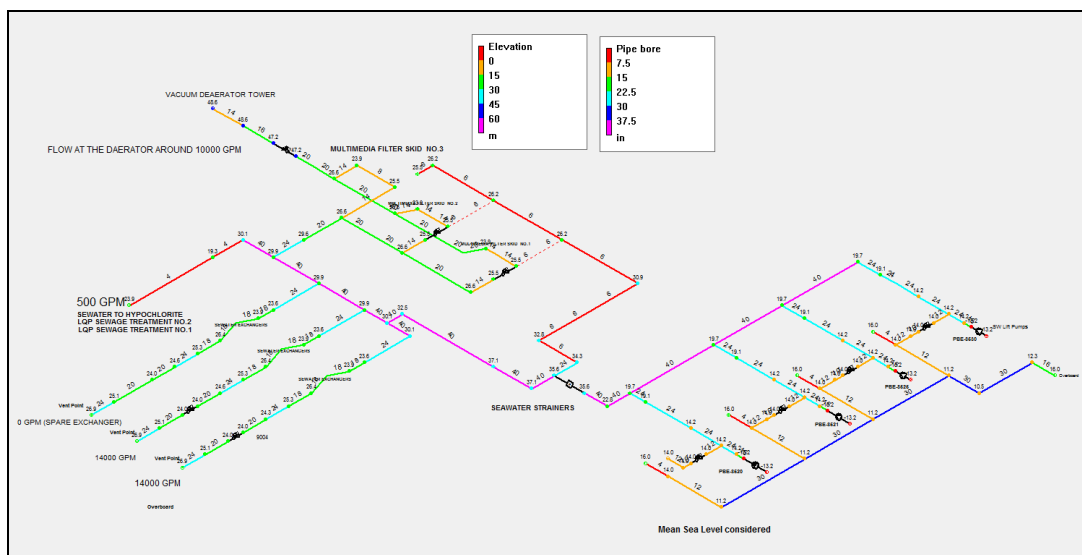
2. Section from Booster Pumps to Water Injection Pumps

In this case, the water injection pumps and booster pumps both trip at the same time. The booster pump is re-started with the water injection pumps still stopped. It can be seen that the water injection pumps spin down more slowly because of their higher moment of inertia. A very small cavity forms in the high point of the bridge connection because the water injection pumps are spinning down more slowly than the booster pumps. The suction effect of this and the higher level of the bridge connection creates a pressure below the vapour pressure. However, the volume of this vapour cavity is very small and its collapse creates oscillations in the pressure rather than a large pressure surge.
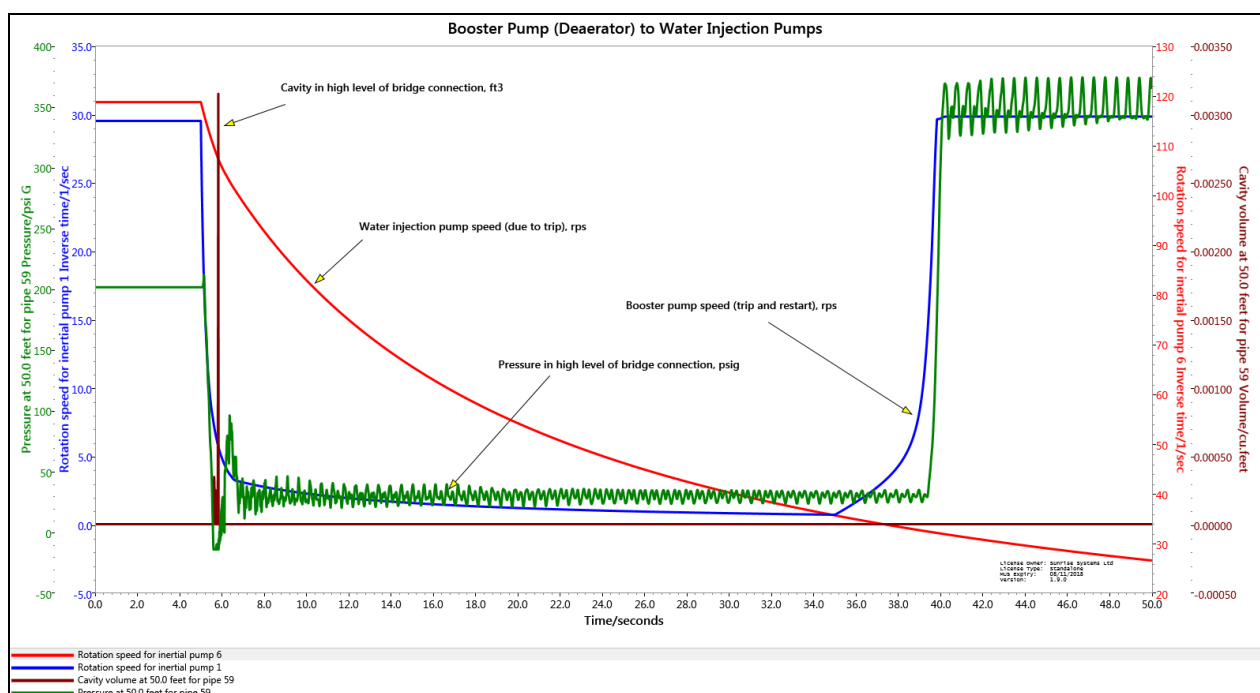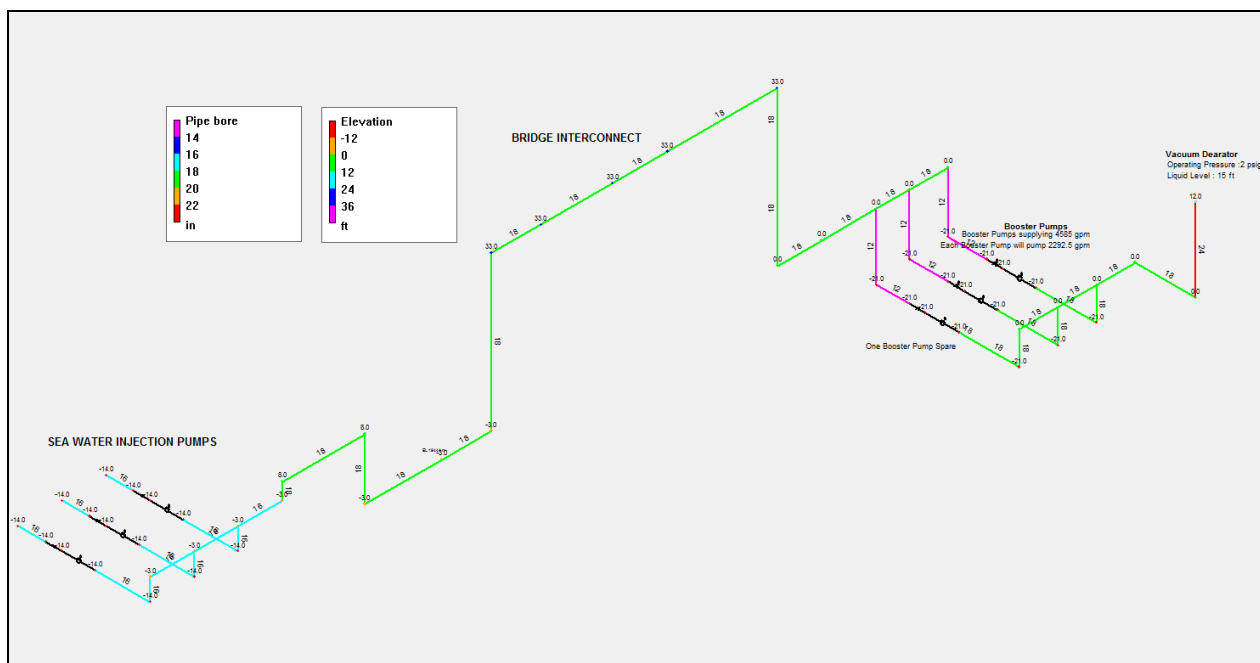
3. Section from Water Injection Pumps to Block Valves at the Wellheads

In this case, all the block valves close at the same time. The water injection pumps continue to run. A flow control valve serves the function of an overboard dump valve. The flow transmitter senses the flowrate in the line downstream of the water injection pumps. The aim of this scenario is to analyse the stability of the flow control system. Instability in the control system can cause vibrations in the overboard dump system. It is assumed that all the block valves at the wellhead close in 1 second.

PIPENET does not perform pipe stress analysis calculations. PIPENET Transient Module generates the force-time history in the form of a file. This file can be read by pipe stress analysis programs such as CaesarII. Such pipe stress analysis programs can predict stresses in pipes, reaction forces in pipe supports and movement in the pipes which can result in vibrations.
In these simulations the following aspects are considered.

- Water hammer at the block valves
- Stability of the overboard dump valve control system
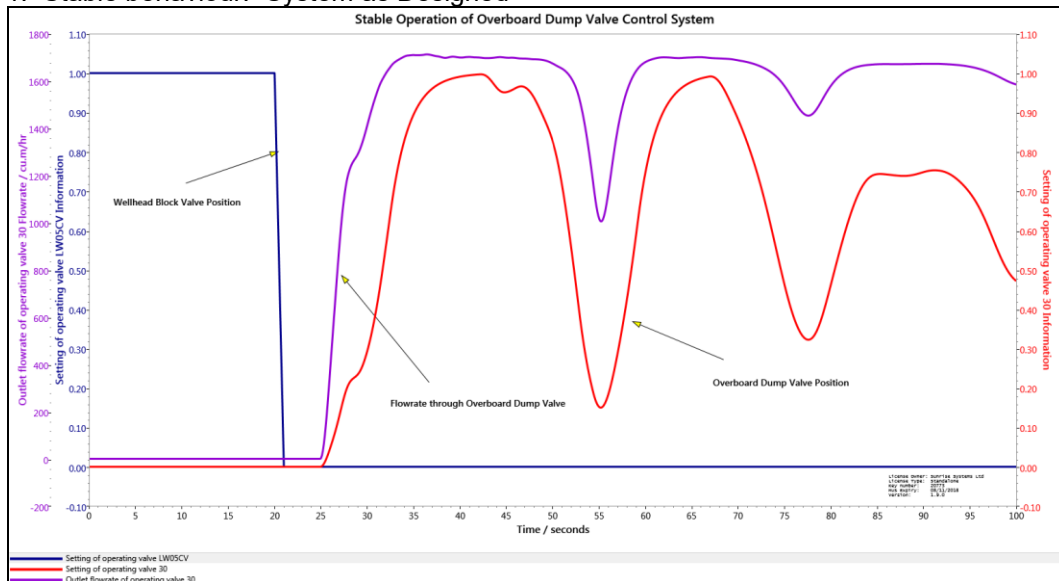- Force-time history on one of the pipe sections in the overboard dump system
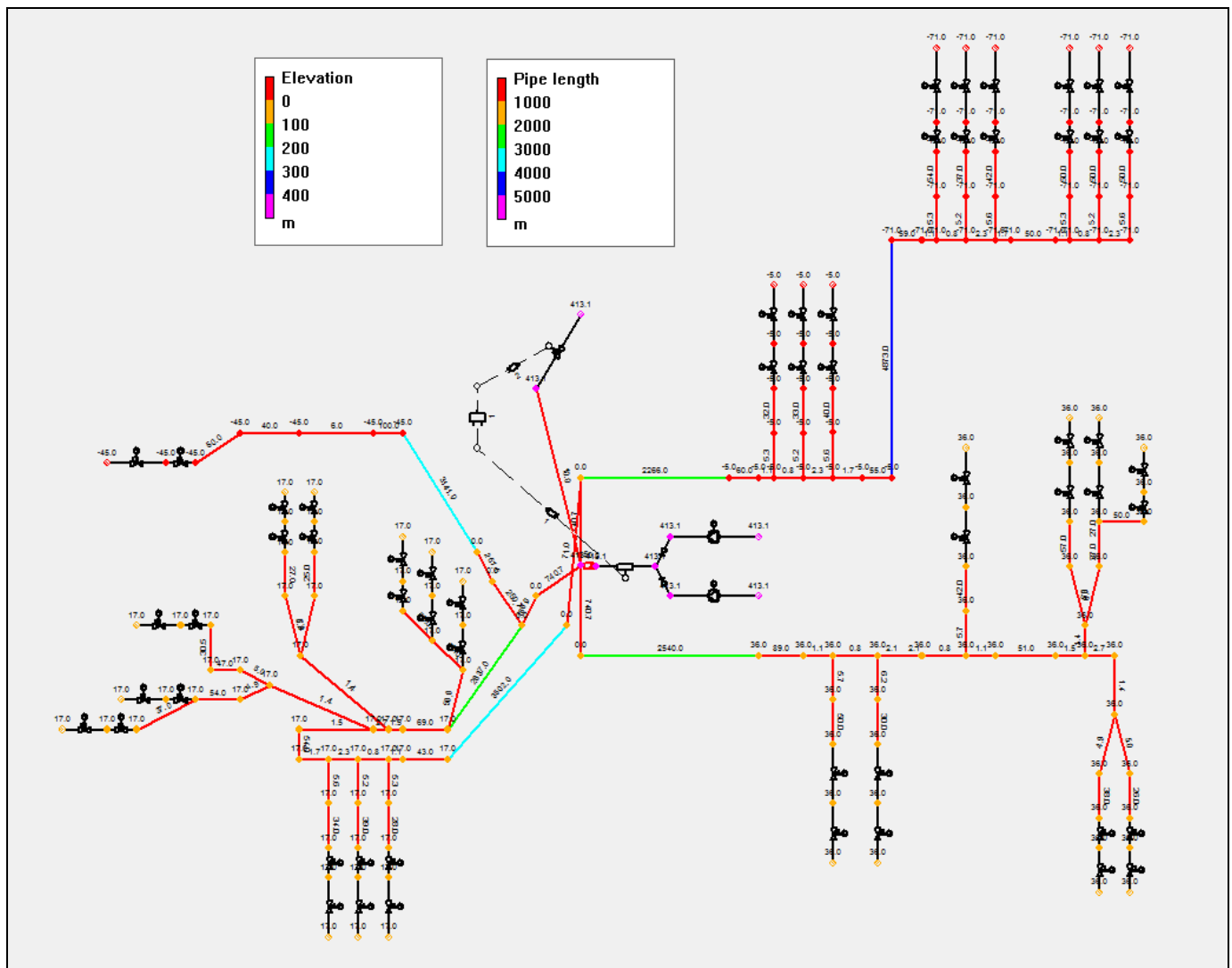
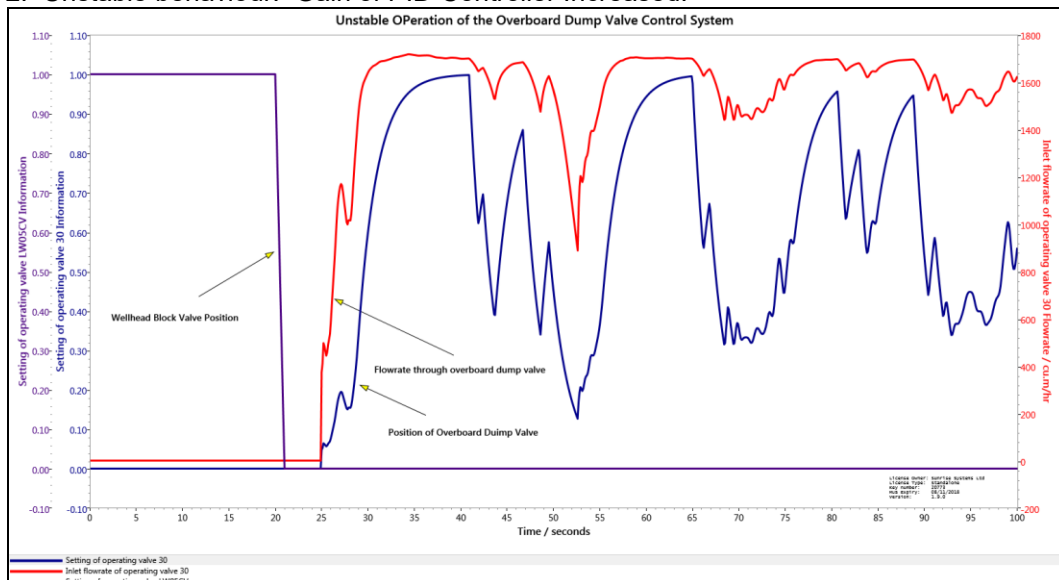## 3.1.   Water Hammer at Block Valve
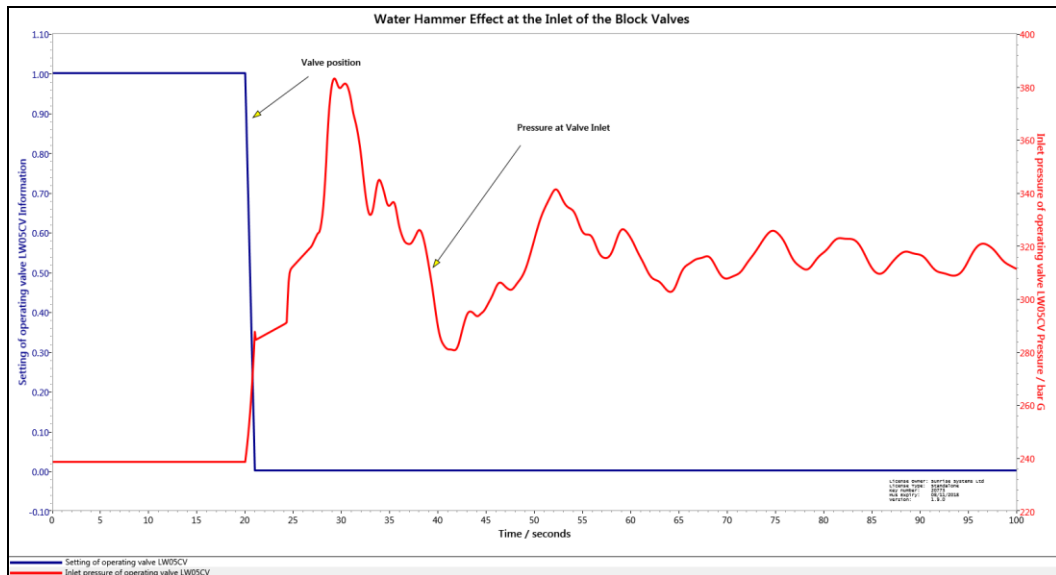
3.2.   Stability of Control System

Case 1: Stable behaviour. System as Designed

Case 2: Unstable behaviour. Gain of PID Controller Increased.

3.3.   Force-Time History with Unstable Control System

The unbalanced force on one pipe on the overboard dump valve system is considered. The pressure surge reaches the input node of this pipe before it reaches the output node. This results in a large unbalanced force in the pipe under consideration.   The unbalanced force is approximately 10,500 Newtons.
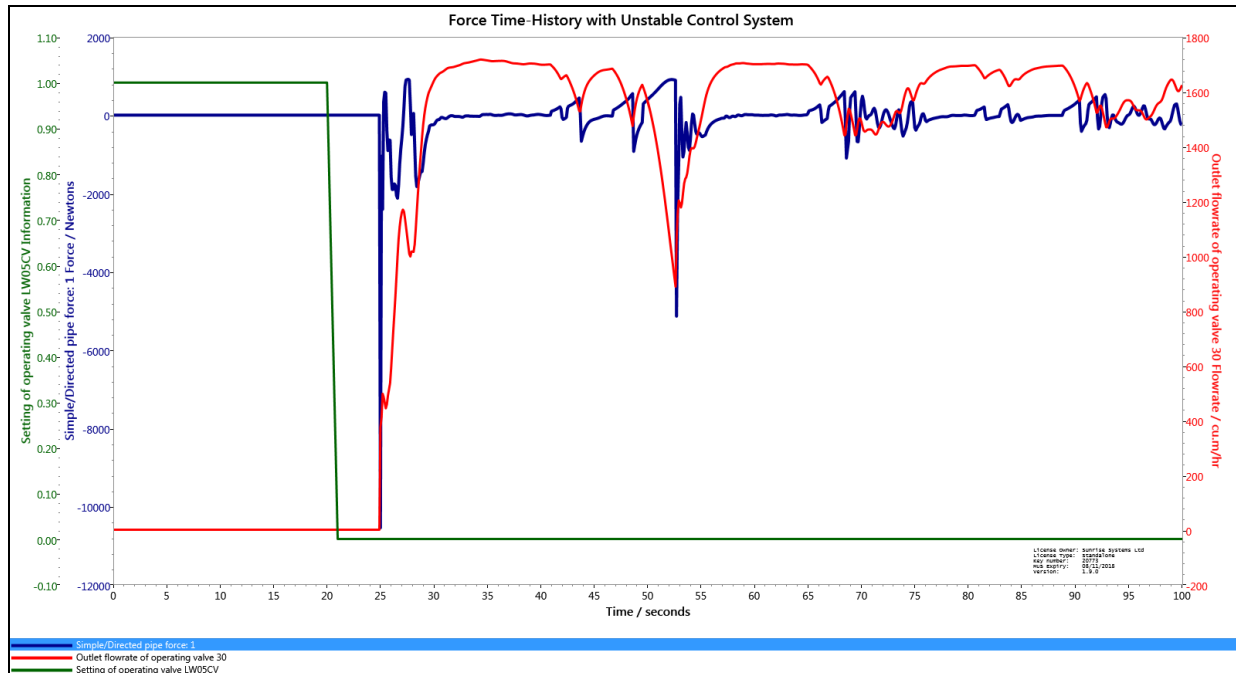
The graph viewer capability in PIPENET has a 'magnifying glass' capability. A couple of graphs with this facility follow.
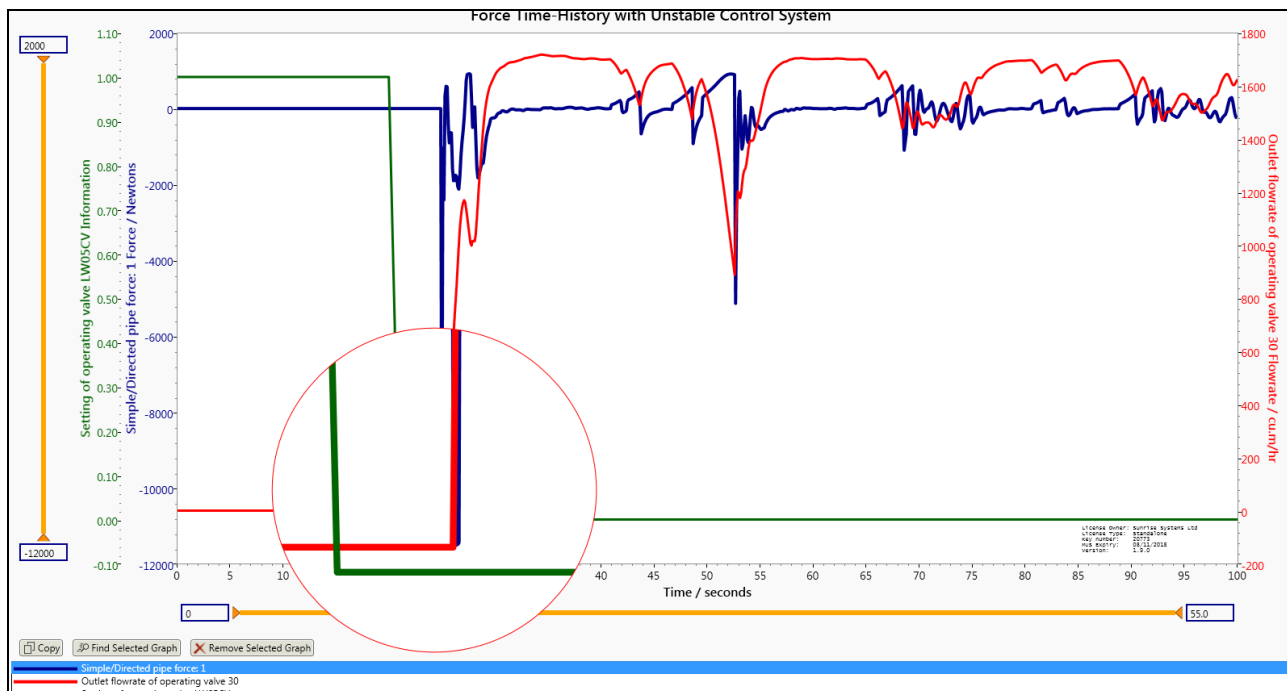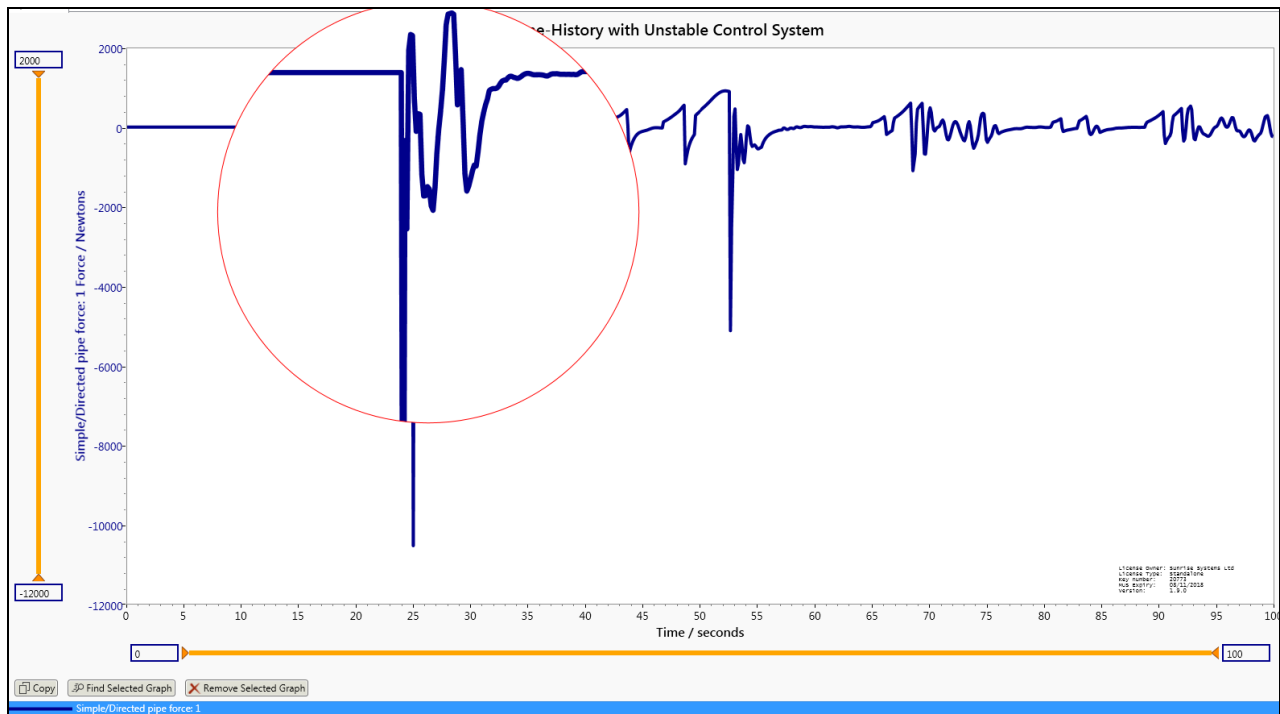
An extract from the force-time history file of PIPENET is shown below. This is the file which can be imported into pipe stress analysis programs such as CaesarII and ROHR2. The first column is time (sec) and the second column is the unbalanced force (Newton).

```
.244000E+2   0.00000
.245000E+2   0.00000
.246000E+2   0.00000
.247000E+2   0.00000
.248000E+2   0.00000
.249000E+2   0.00000
.250000E+2  -10546.3
.251000E+2  -1046.48
.252000E+2  -2408.99
.253000E+2   340.604
.254000E+2   587.157
.255000E+2   570.952
.256000E+2  -398.961
.257000E+2  -905.902
.258000E+2  -633.441
.259000E+2  -641.969
```

CONCLUSIONS

This brief document gives an introduction to water injection system applications of PIPENET. It endeavours to demonstrate that PIPENET can be used to model all aspects of water injection systems. This includes establishing potential water hammer problems, cavity formation and collapse, sequence in which booster pumps and water injection pumps should be started and the calculation of unbalanced force-time history with the view of further processing by pipe stress analysis programs.

Sensitivity Analysis of the Control System on a Pipeline

Modelling control loops is one of the outstanding capabilities of PIPENET. The article below provides an example of a sensitivity analysis of the control system on a pipeline. The network has 3 pumps of which one pump is running at its design speed in this scenario. The other two pumps are shut down. The system has two flow control valves which are identical. The described scenarios consider the response of the control valve to one of the isolation valves closing. The isolation valve which is closing is valve 2.
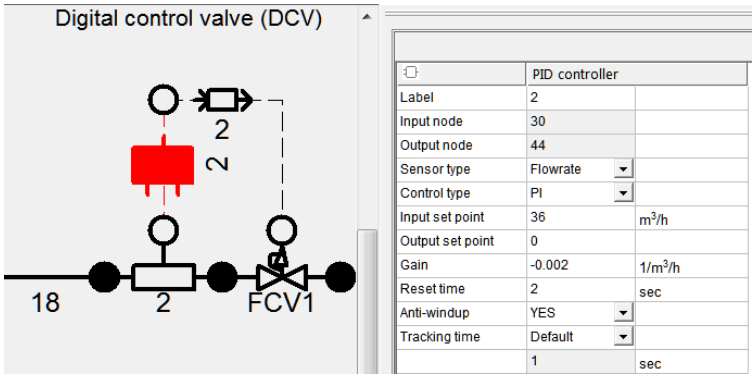
1. The network.
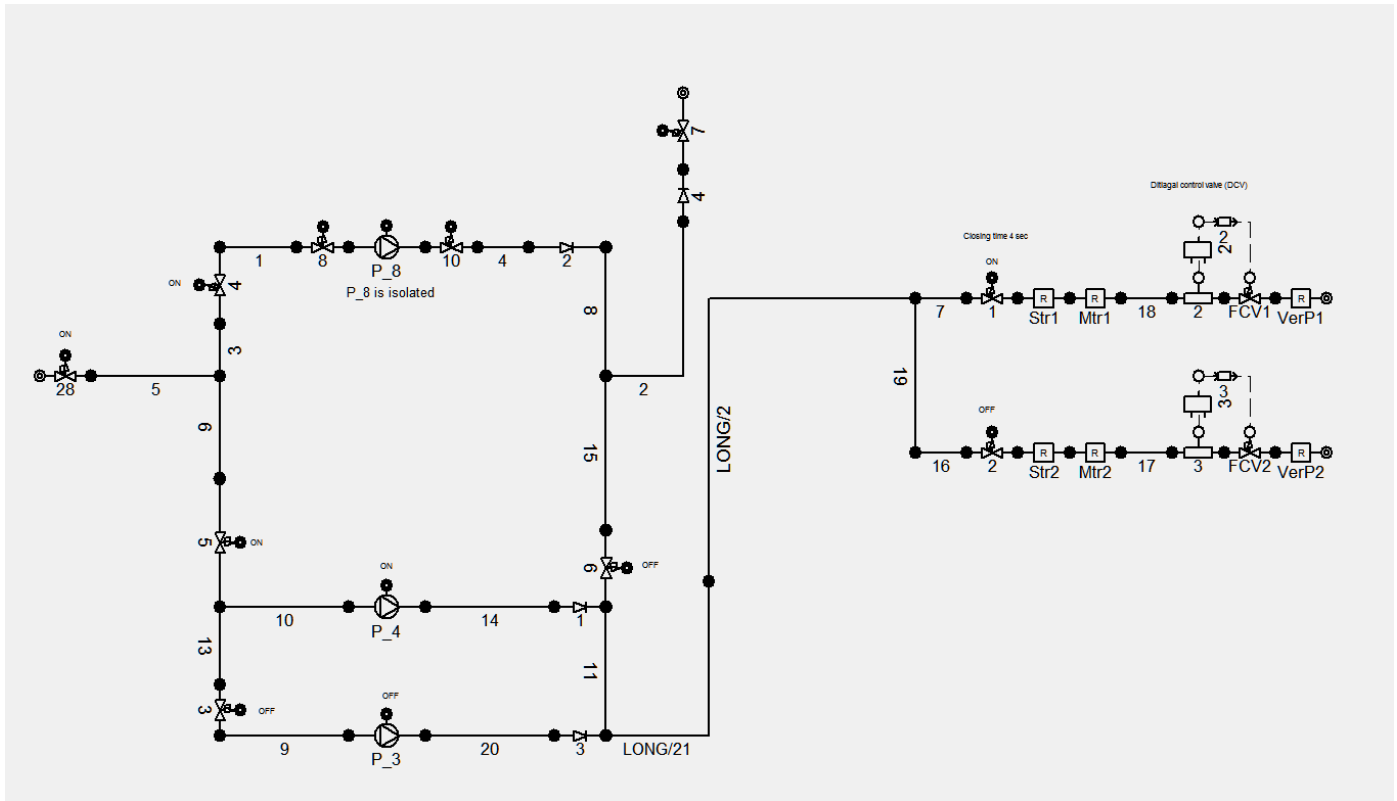
2. The control system.

PIPENET has comprehensive capabilities for building control systems including loops such as cascade control, signal selector, switches and so on. In this network the control system is built using a flow sensor, PID controller, first order transfer function, and the control valve.
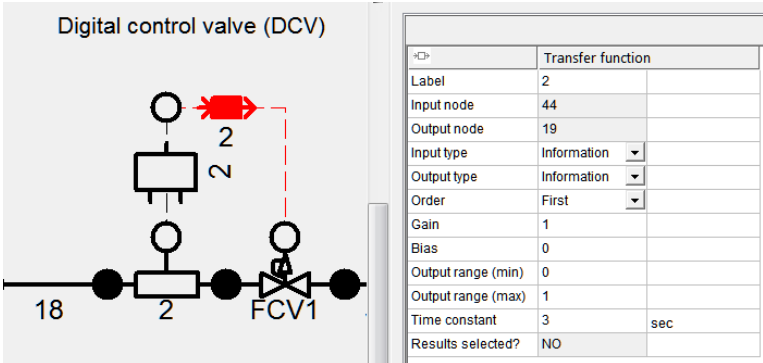
Flow sensor: Flow sensor 2 is in-line with pipe 18. It is selected to be of the analogue type. For this reason, there is no sampling time.
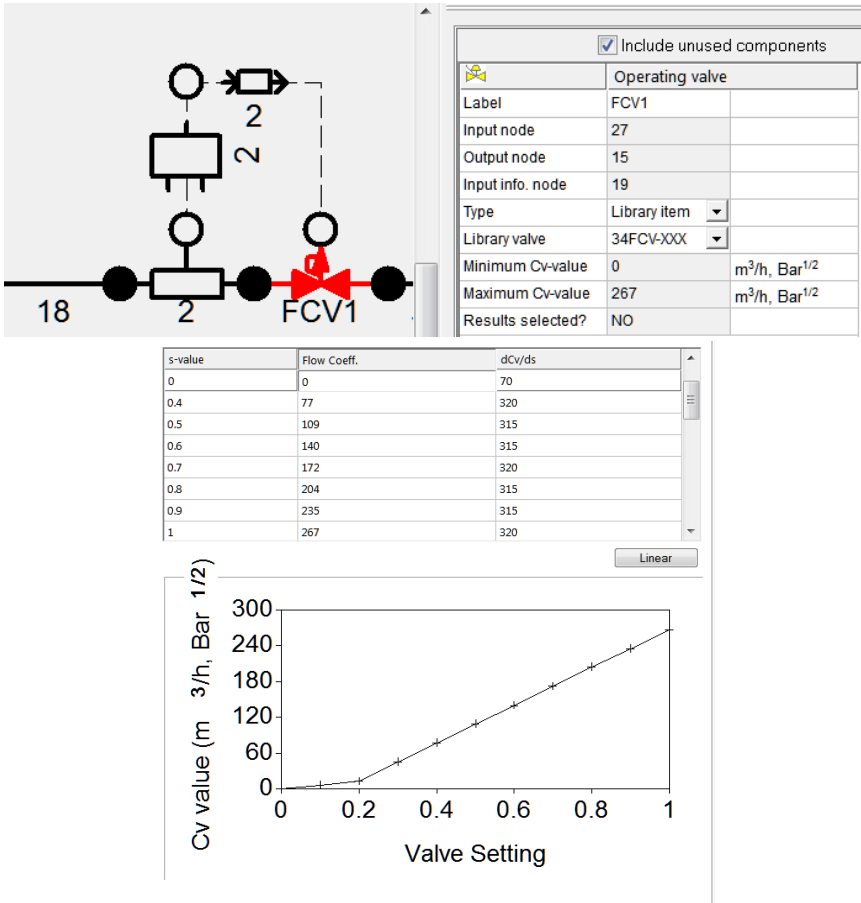

Digital control valve (DCV)
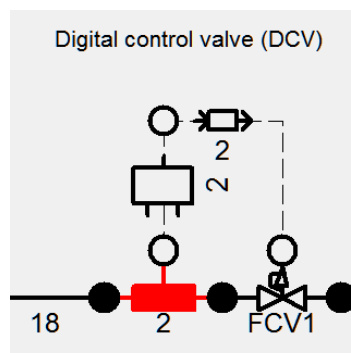
The PID controller is selected to be of the PI type. The parameters are shown in the dialog box below.

	PID controller	
Label	2	
Input node	30	
Output node	44	
Sensor type	Flowrate	
Control type	PI	
Input set point	36	m³/h
Output set point	0	
Gain	-0.002	1/m³/h
Reset time	2	sec
Anti-windup	YES	
Tracking time	Default	
	1	sec

The transfer function model shown below represents the dynamics of the control valve. In general, a control valve will not respond instantly to a change in the input signal. Typically, the dynamics of this is modelled by using a transfer function. PIPENET offers a choice of zeroth, first and second order transfer functions. In this model the first order transfer function model is used with a time constant of 3 secs.

	Transfer function	
Label	2	
Input node	44	
Output node	19	
Input type	Information	
Output type	Information	
Order	First	
Gain	1	
Bias	0	
Output range (min)	0	
Output range (max)	1	
Time constant	3	sec
Results selected?	NO	

The control valve and its characteristics are shown below.

☑ Include unused components

	Operating valve	
Label	FCV1	
Input node	27	
Output node	15	
Input info. node	19	
Type	Library item	
Library valve	34FCV-XXX	
Minimum Cv-value	0	m³/h, Bar^{1/2}
Maximum Cv-value	267	m³/h, Bar^{1/2}
Results selected?	NO	

| s-value	Flow Coeff.	dCv/ds
0	0	70
0.4	77	320
0.5	109	315
0.6	140	315
0.7	172	320
0.8	204	315
0.9	235	315
1	267	320

Linear

3. The Scenarios.

Three scenarios are considered in this study. The aim is to both understand the behaviour of the system and to make sure that the control system is stable.
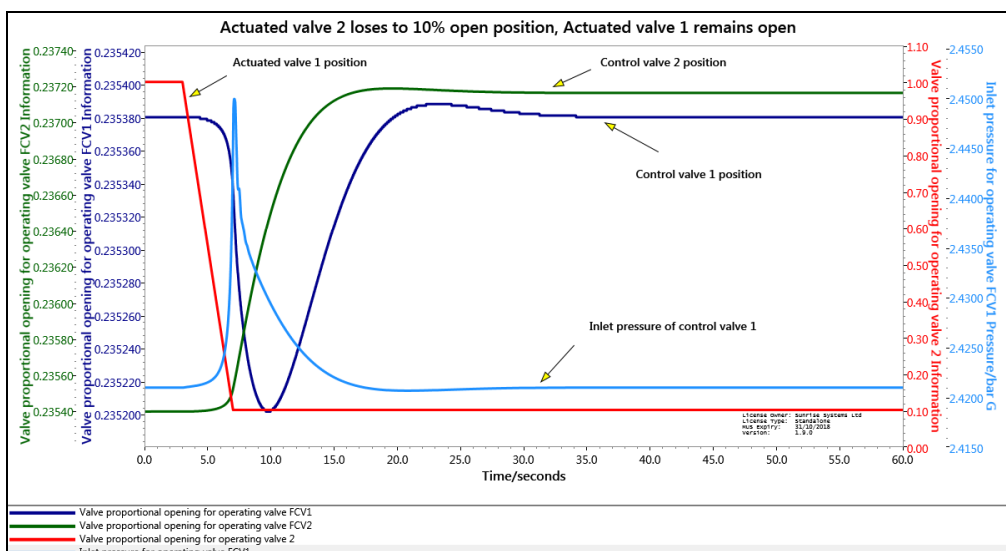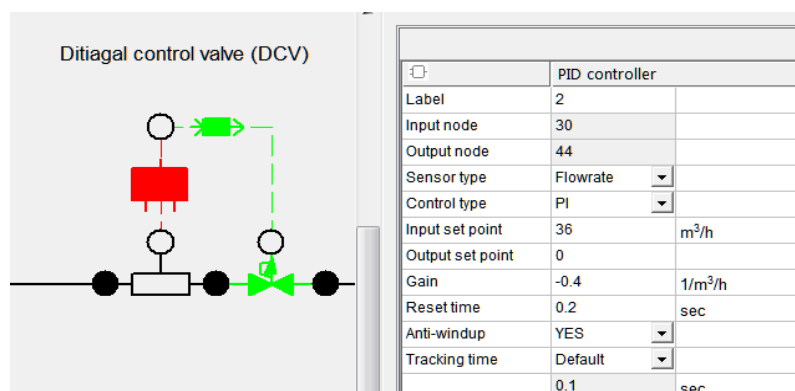
Scenario 1: Actuated valve 2 fully closes, actuated valve 1 remains fully open

We can make the following observations. When the actuated valve 2 closes, the flow is directed towards control valve 1. In order to compensate for this the control valve closes slightly. There is a small overshoot before it comes back to its final steady state position. On the other hand, control valve 2 opens fully. This is because when the actuated valve fully closes, it tries to maintain the flow at its set point. The behaviour of the system is smooth and no instability is observed.
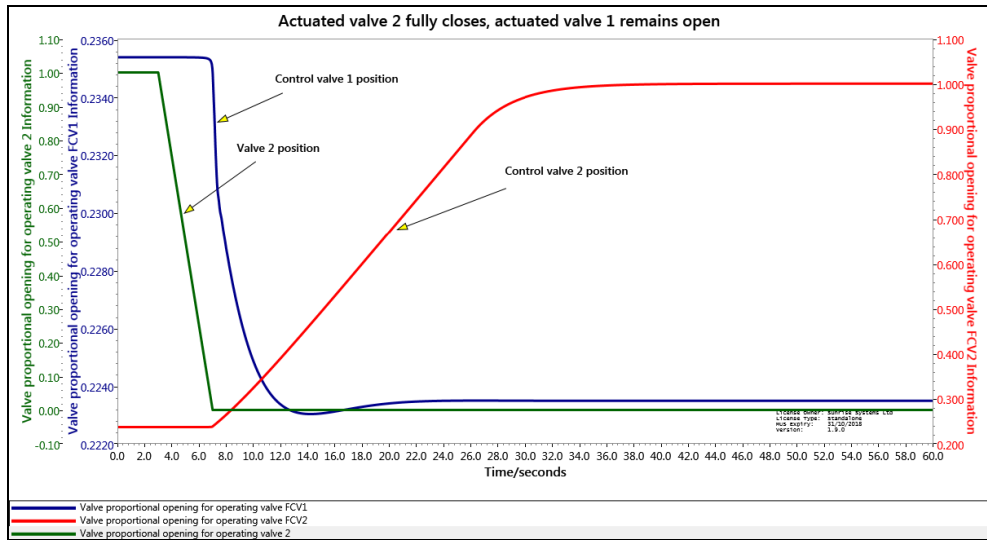
Scenario 2: Actuated valve 2 closes to 10% open position, actuated valve 1 remains fully open

We can make the following observations. When the actuated valve 2 closes to its 10% open position, more flow is directed towards control valve 1. In order to compensate for this the control valve closes slightly. However, as the actuated valve does not fully close control valve 2 is able to open sufficiently in order to restore its flow rate to the set point. When this happens, control valve 1 goes back to its original position and the flow is restored. The behaviour of the system is smooth and no instability is observed.

Scenario 3: Actuated valve 2 closes to 10% open position, actuated valve 1 remains fully open with faster control system

The PID controller parameters are shown below.

Ditiagal control valve (DCV)

	PID controller	
Label	2	
Input node	30	
Output node	44	
Sensor type	Flowrate	
Control type	PI	
Input set point	36	m^3/h
Output set point	0	
Gain	-0.4	$1/m^3/h$
Reset time	0.2	sec
Anti-windup	YES	
Tracking time	Default	
	0.1	sec

We can make the following observations. The basic behaviour is similar to scenario 2. When the actuated valve 2 closes to its 10% open position, more flow is directed towards control valve 1. In order to compensate for this the control valve closes slightly. However, as the actuated valve does not fully close control valve 2 is able to open sufficiently in order to restore its flow rate to the set point. When this happens, control valve 1 goes back to its original position and the flow is restored.

The main point to note however is that the system is unstable and there are oscillations in the valve position.
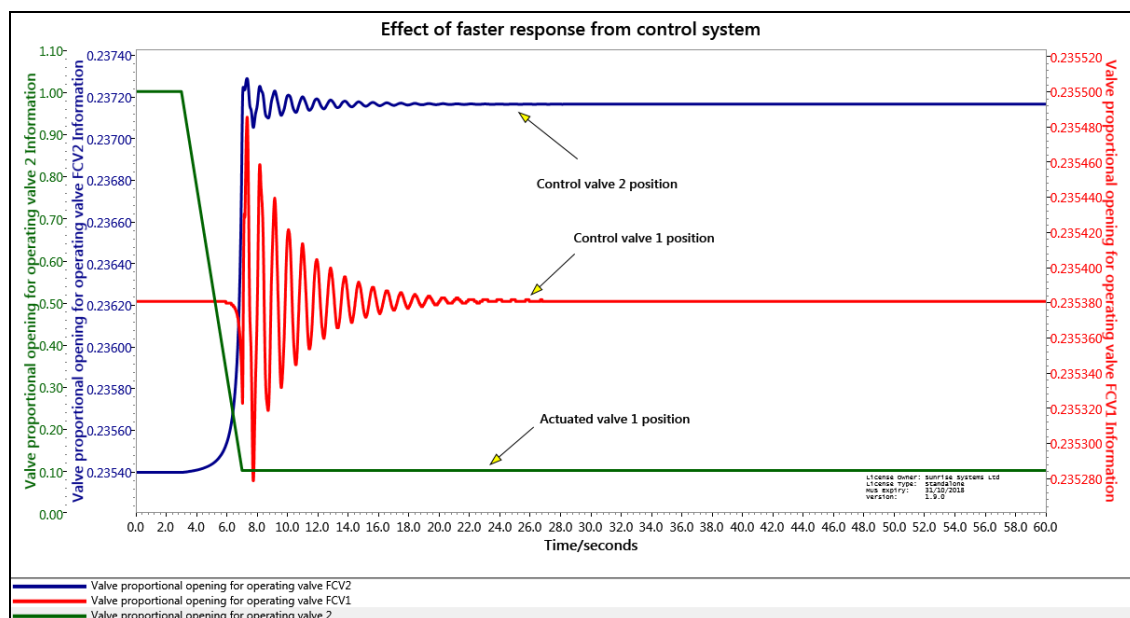
How to Create Alternative Networks by Combining Systems

The purpose of this document is to show how to combine different sub-networks to a common network in order to create different networks.

1. Complete System:
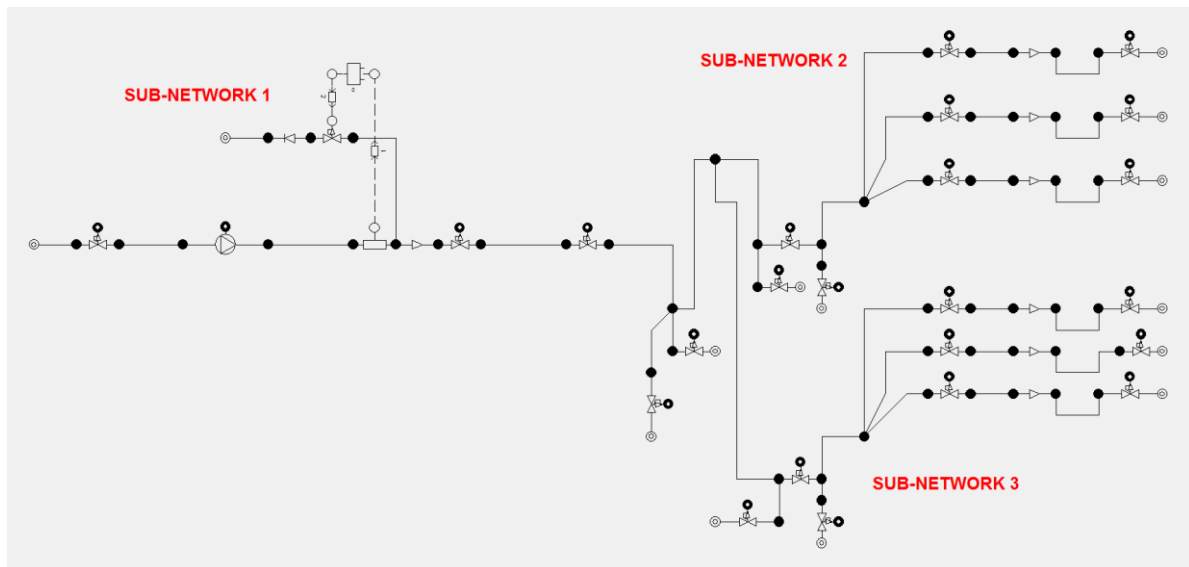
2. Case 1 System: Common network (sub-network 1) with sub-network 2 attached
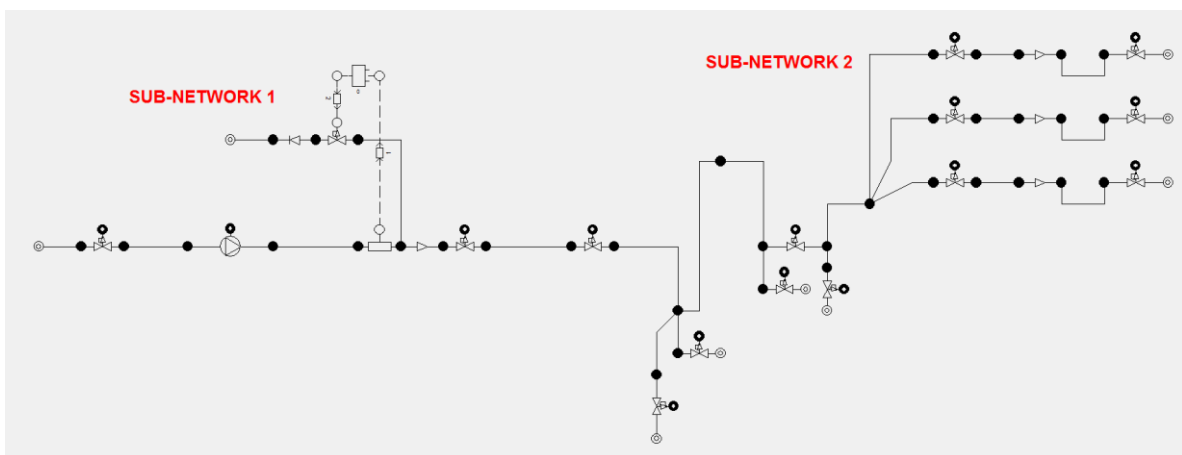
3. Case 2 System: Common network (sub-network 1) with sub-network 3 attached
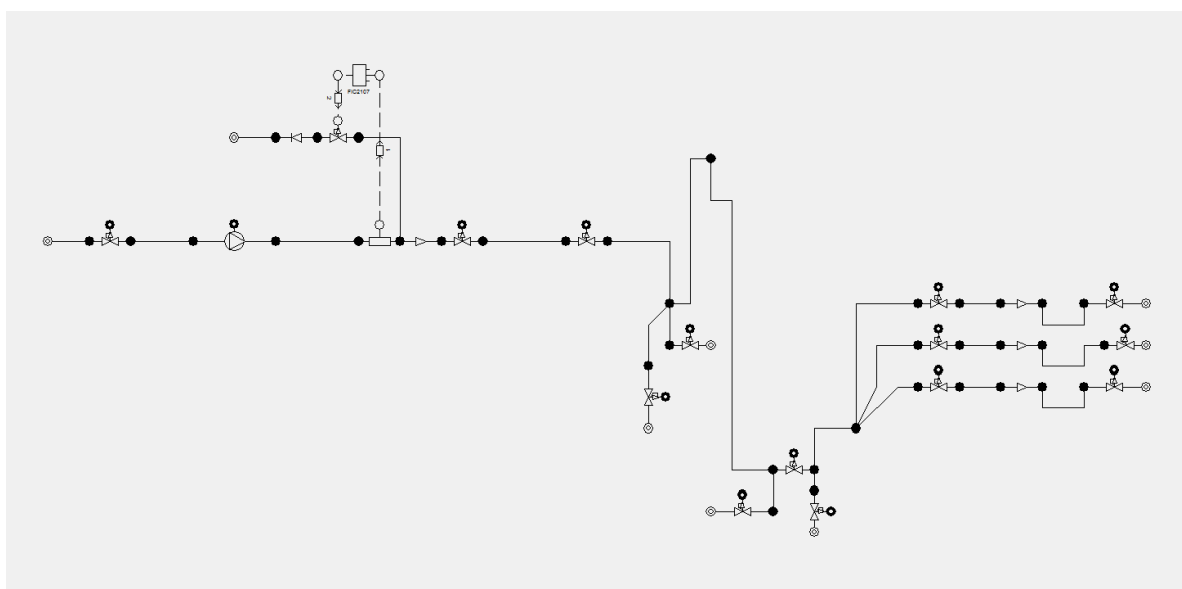
METHOD 1 – CREATING A SET OF SUB-NETWORKS AND COMBINING THEM

This method has the advantage that it is possible to have sets of several network types and combine them as required. It is more flexible than method 2.

Step 1: Create three sub-networks and save them on three separate files but with the same library.

Sub-network 1
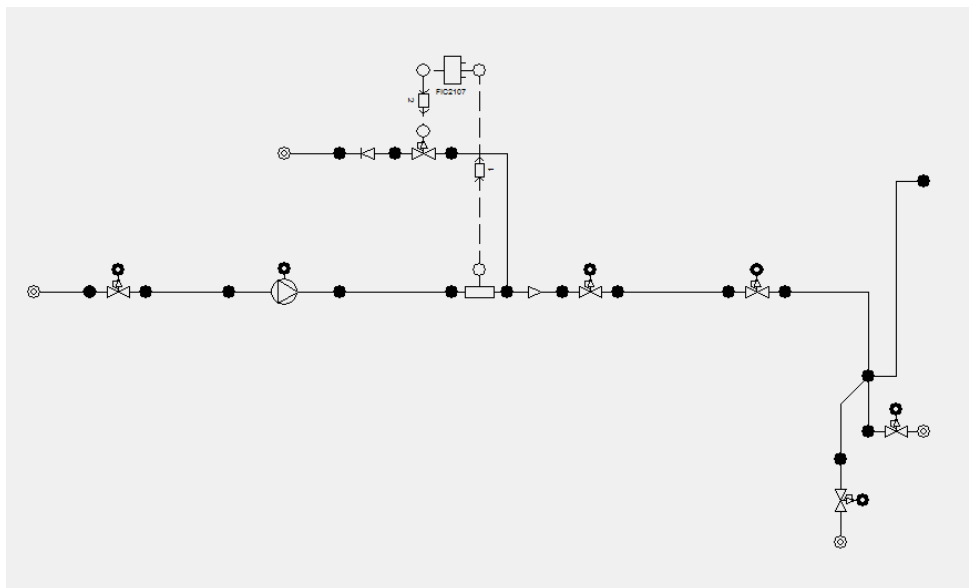
Sub-network 2
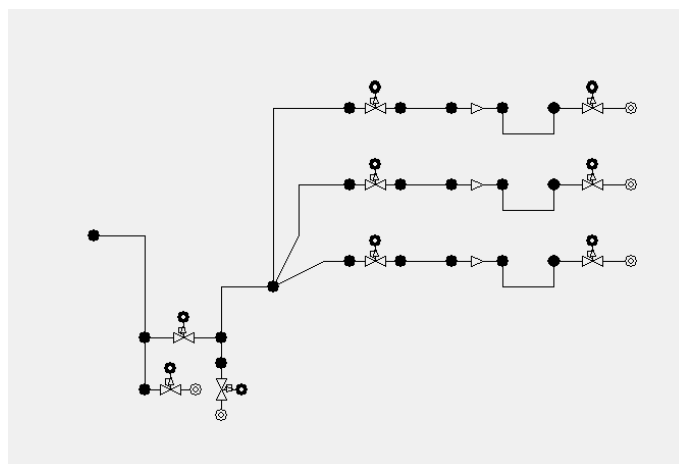
Sub-network 3
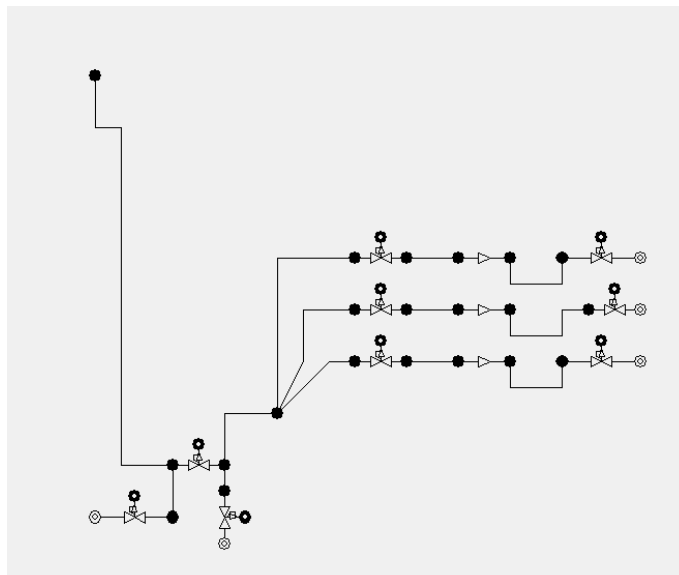
Step 2: Combine the sub-networks as required. In this case we show how to combine sub-networks 1 and 2.

Start two copies of PIPENET on your computer and open the subnetworks on the copies of PIPENET.
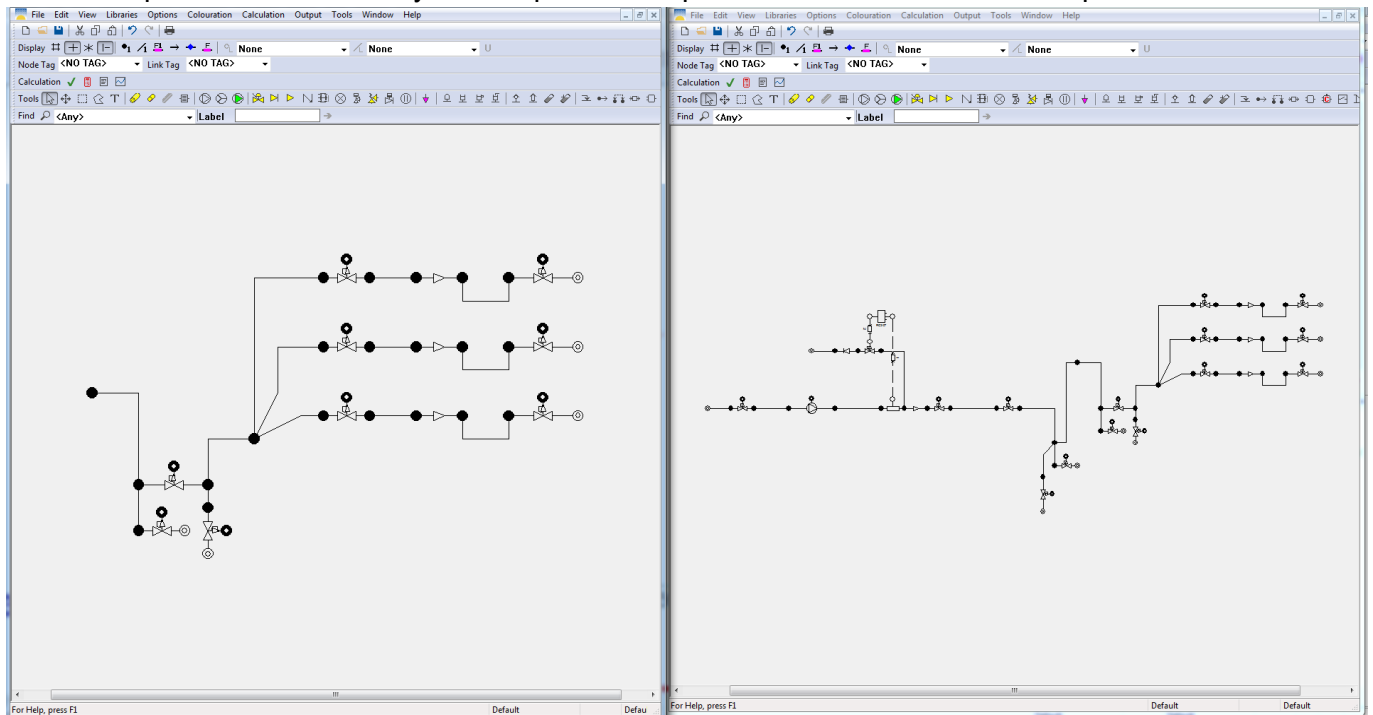
Use the area tool to capture subnetwork 2.
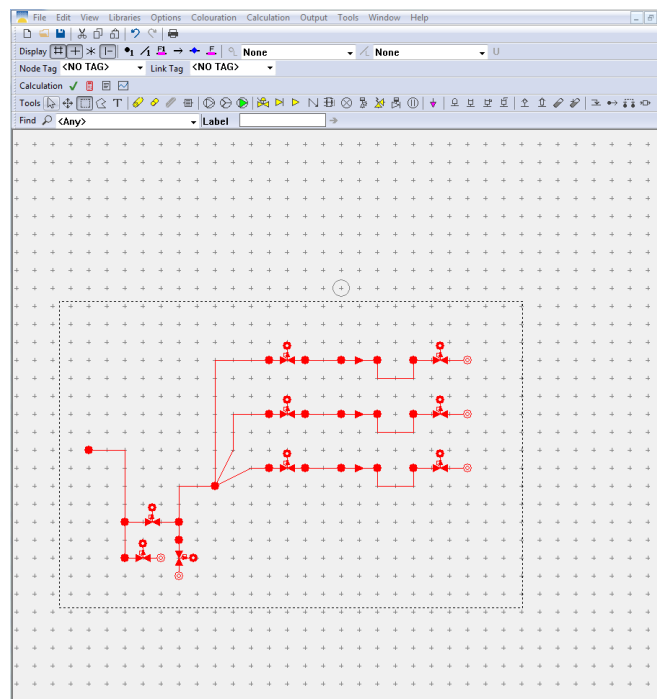
Move the captured subnetwork 2 to the lower end of the screen as shown below.
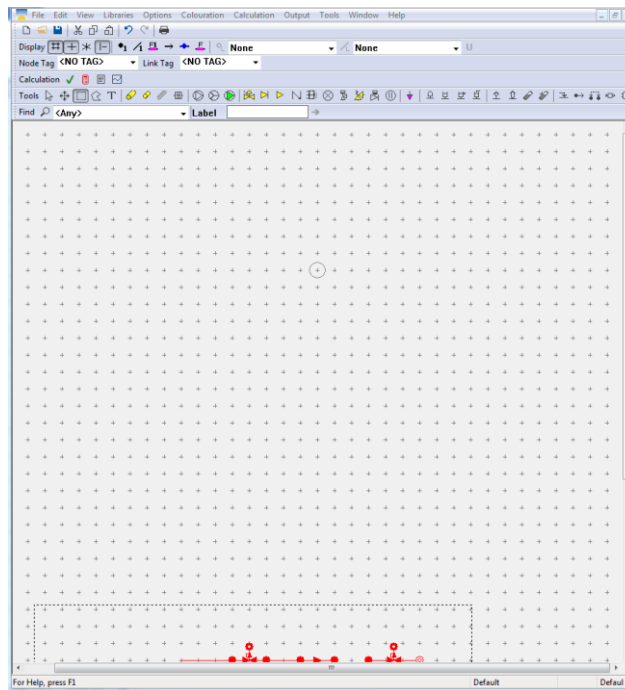
Right click on the captured area and click on 'copy'
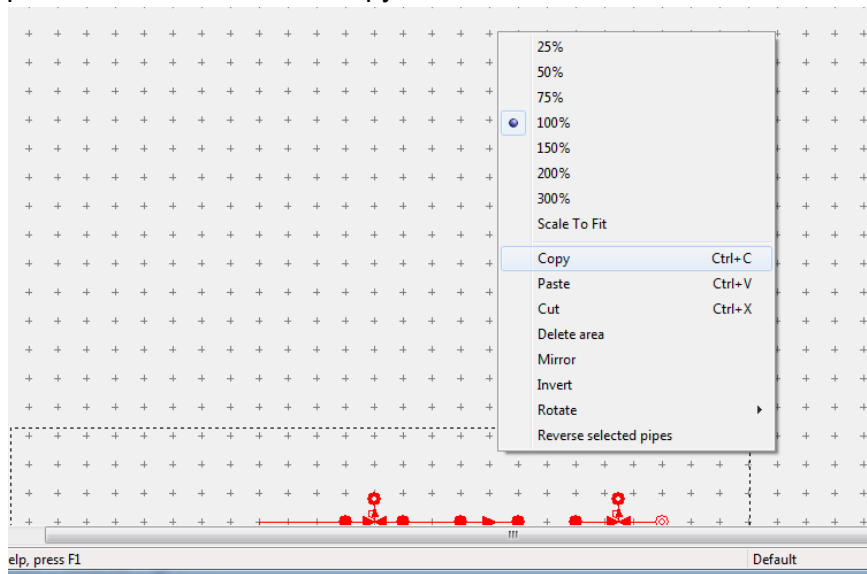
Go to the copy of PIPENET with the copy of subnetwork 1, select the area tool and click on 'Edit/Paste'
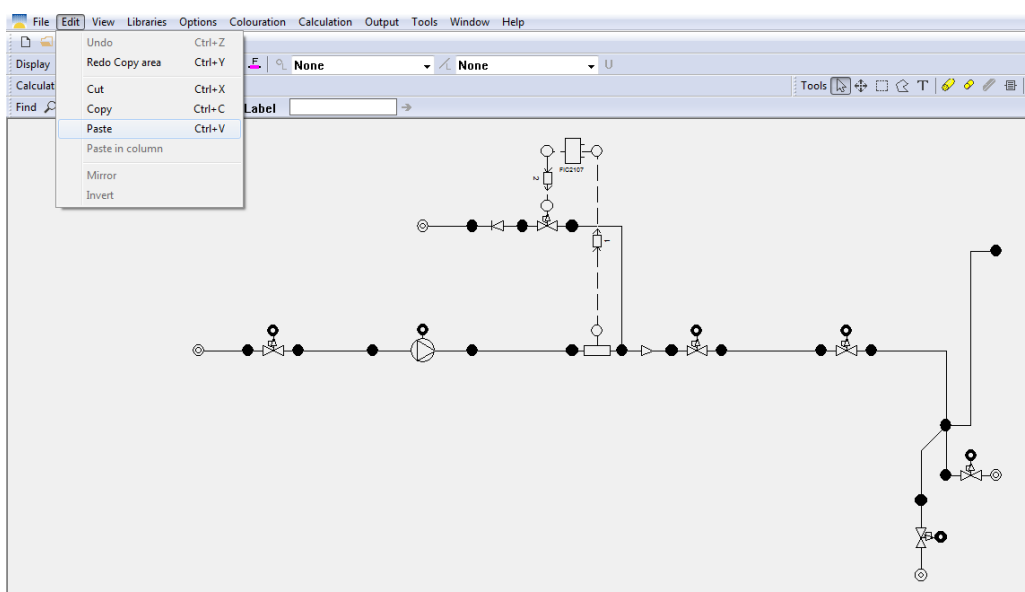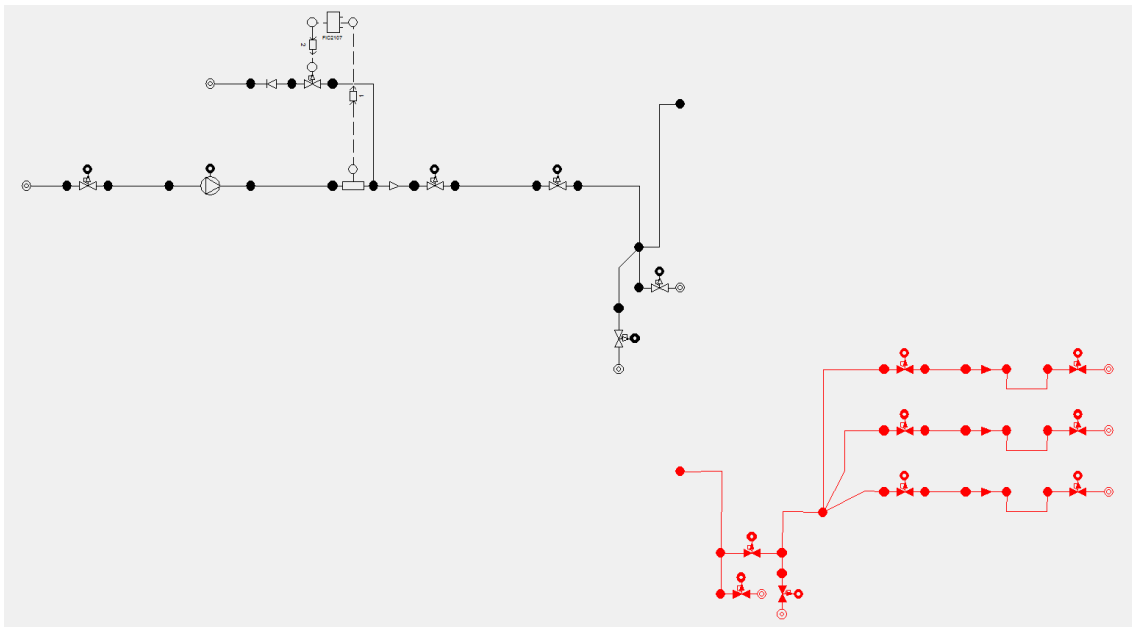
Now capture subnetwork 2 using the area tool. It is useful to have the grid on at this time.
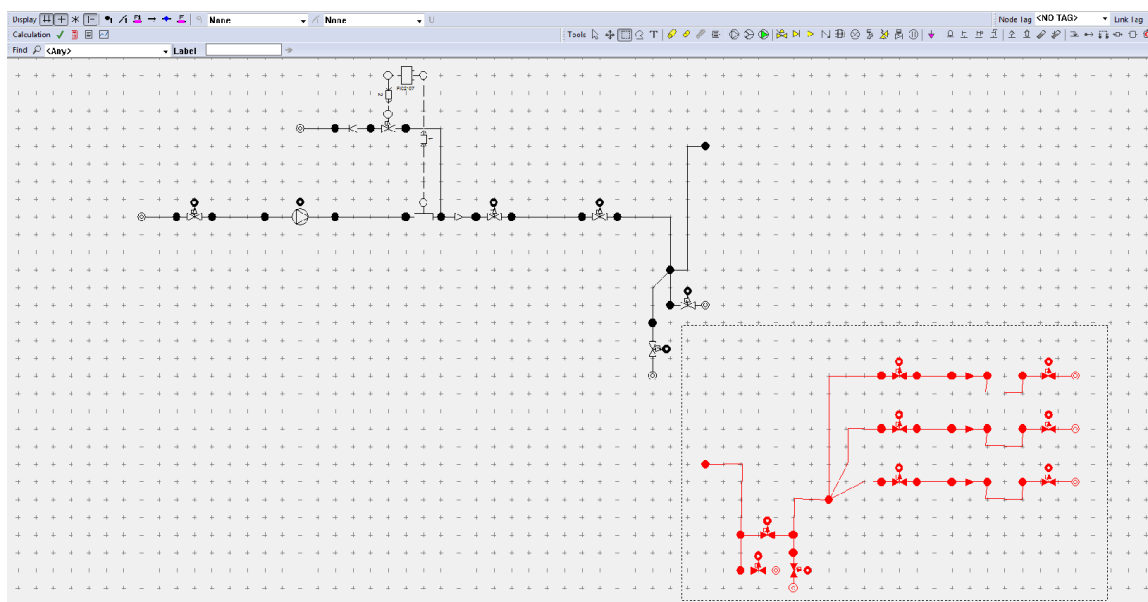
Click and hold the node in subnetwork 2 which is connected to subnetwork 1 and move it to the relevant node.
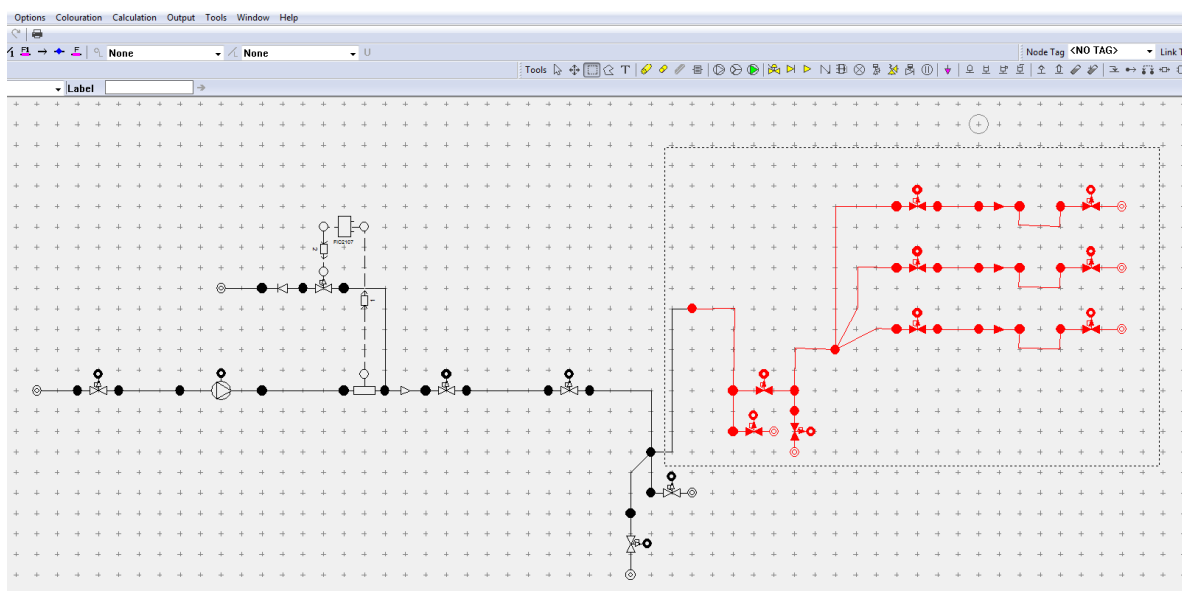
Now pick up the cursor, click on the node where subnetwork 1 and subnetwork 2 are connected and merge the nodes.
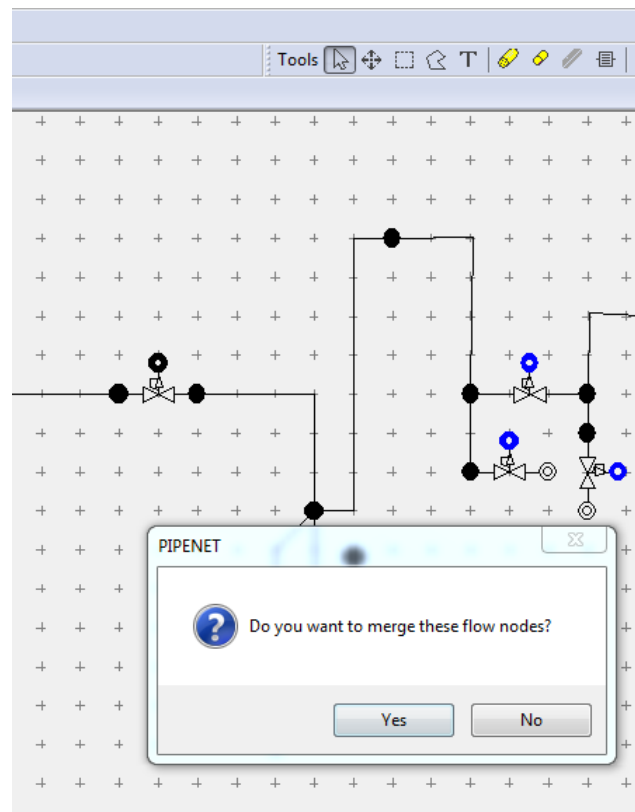
Please note the following
    (i)   PIPENET will automatically re-label links and nodes if there is duplication.

    (ii) If any item is shown in blue and you feel it should be black please click on the tick (check)
        mark
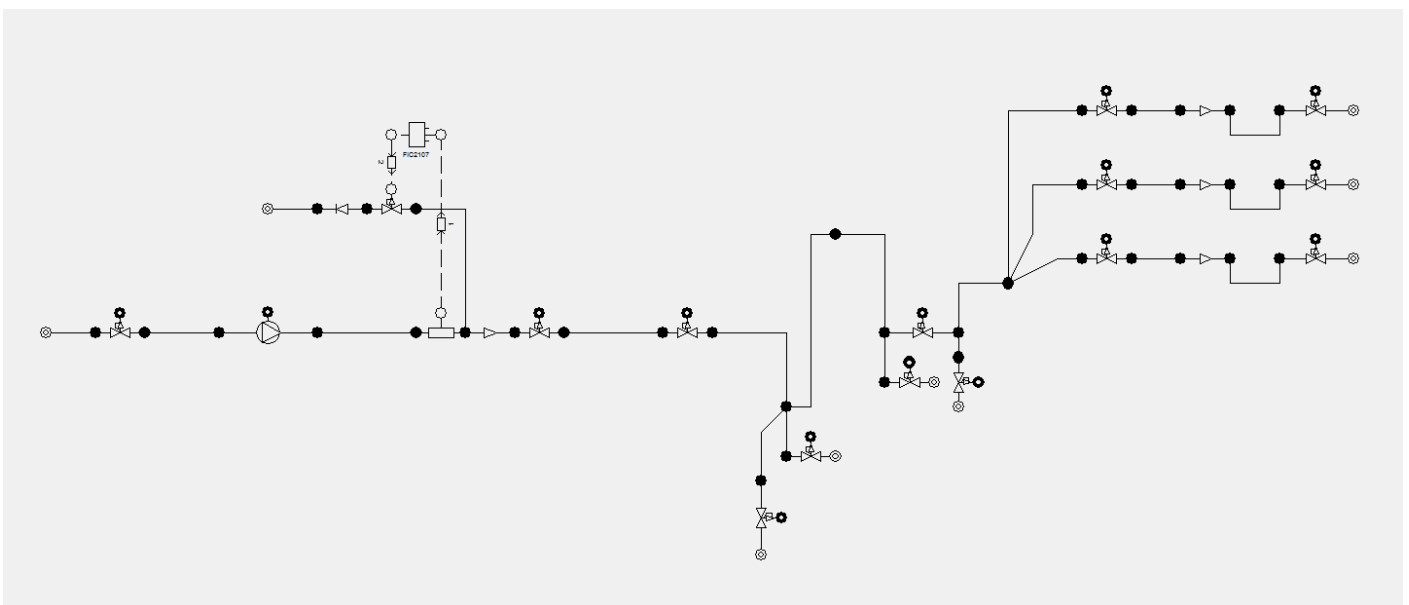
METHOD 2 – CREATE A MASTER NETWORK AND DELETE SUB-NETWORKS AS REQUIRED

By this method you can create a master network and delete sub-networks. This is simpler. On the other hand, it does not have the flexibility of having several sets of sub-networks and combining them as required.

Step 1: Create the master network.
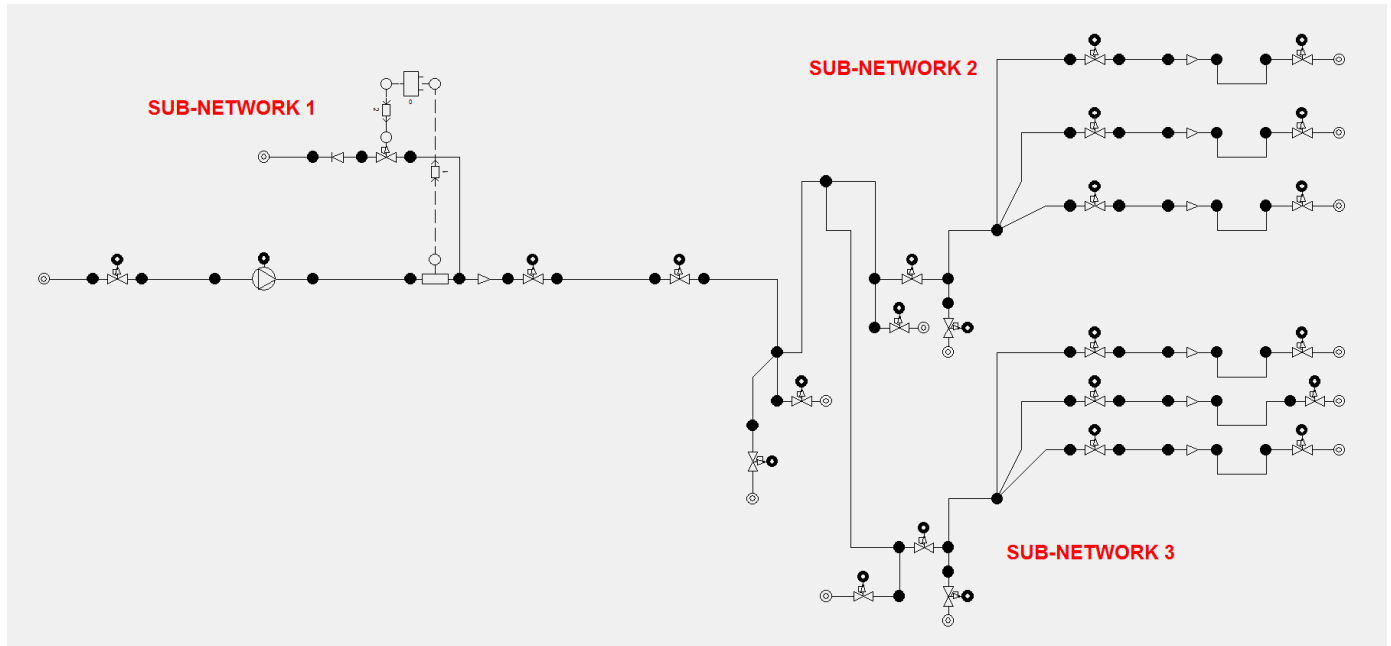
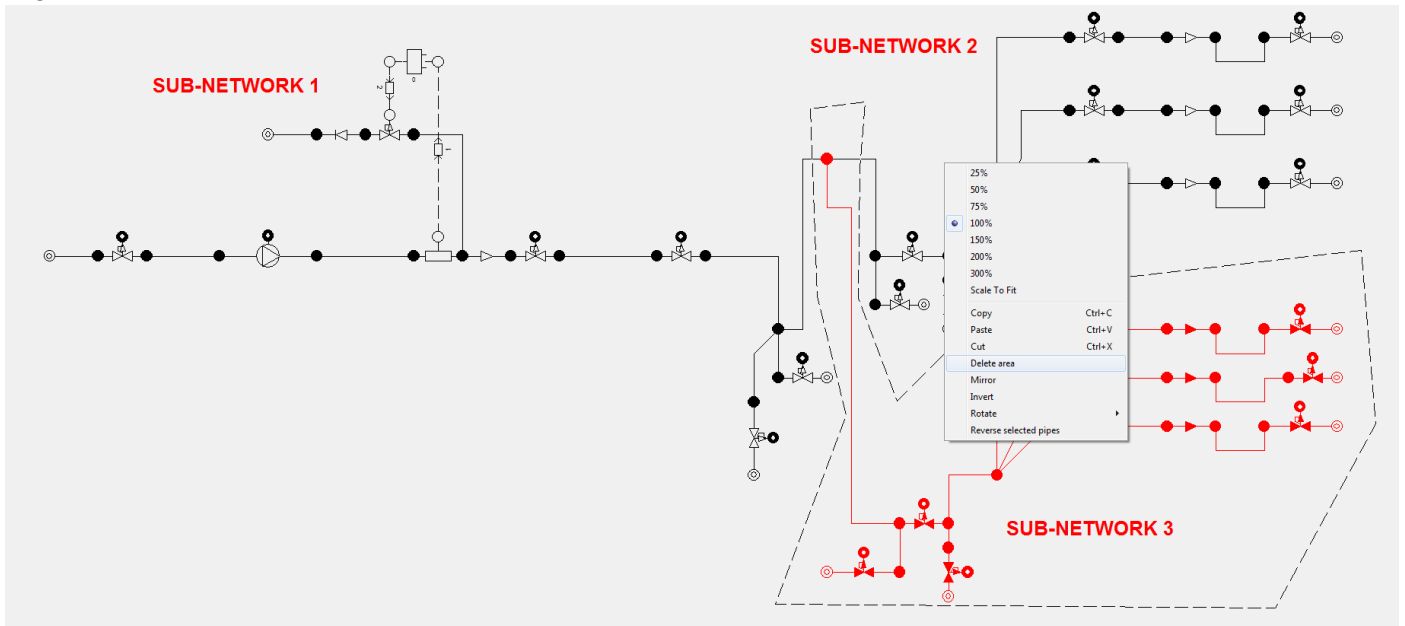**Step 2: Delete the sub-network which is not required.**

Select the polygon tool.

Keep the 'Shift' button on the keyboard pressed and use the cursor to enclose the area you wish to delete. Note that an item must be completely within the polygon for it to be selected.
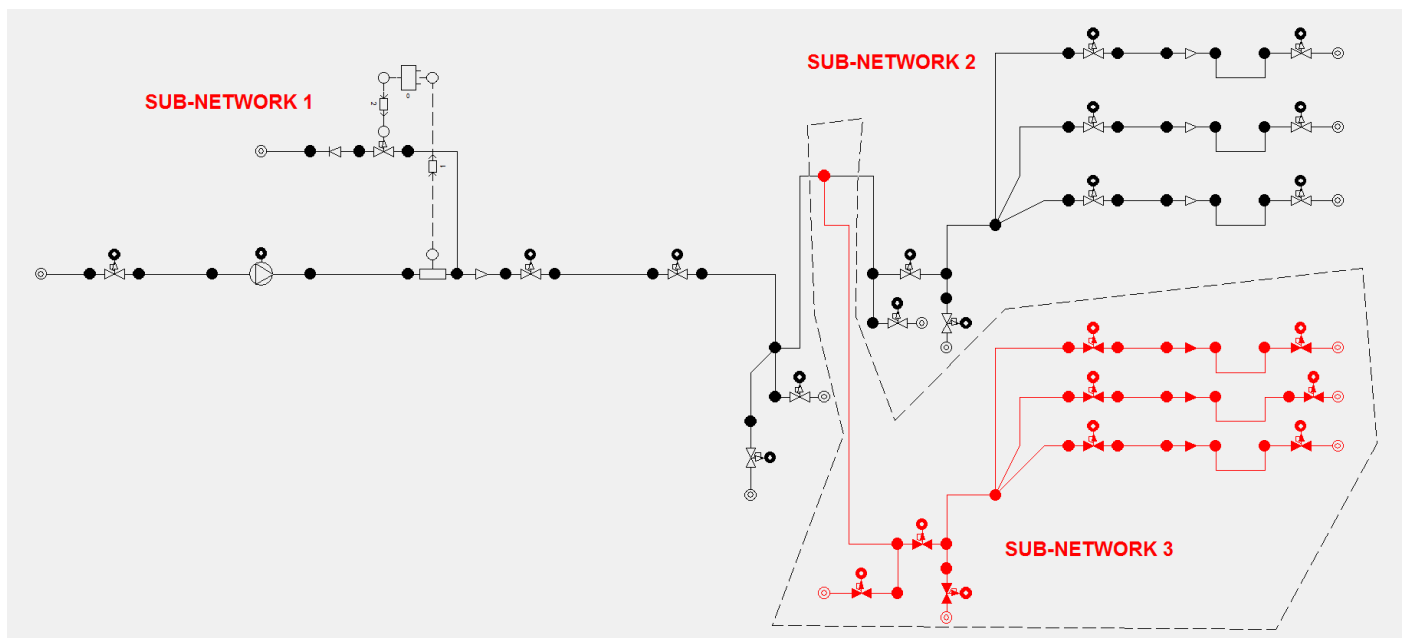
Right click with the cursor inside the area to be deleted. Click on 'Delete area'.

Now the selected area has been deleted. The polygon can be removed by selecting the cursor.
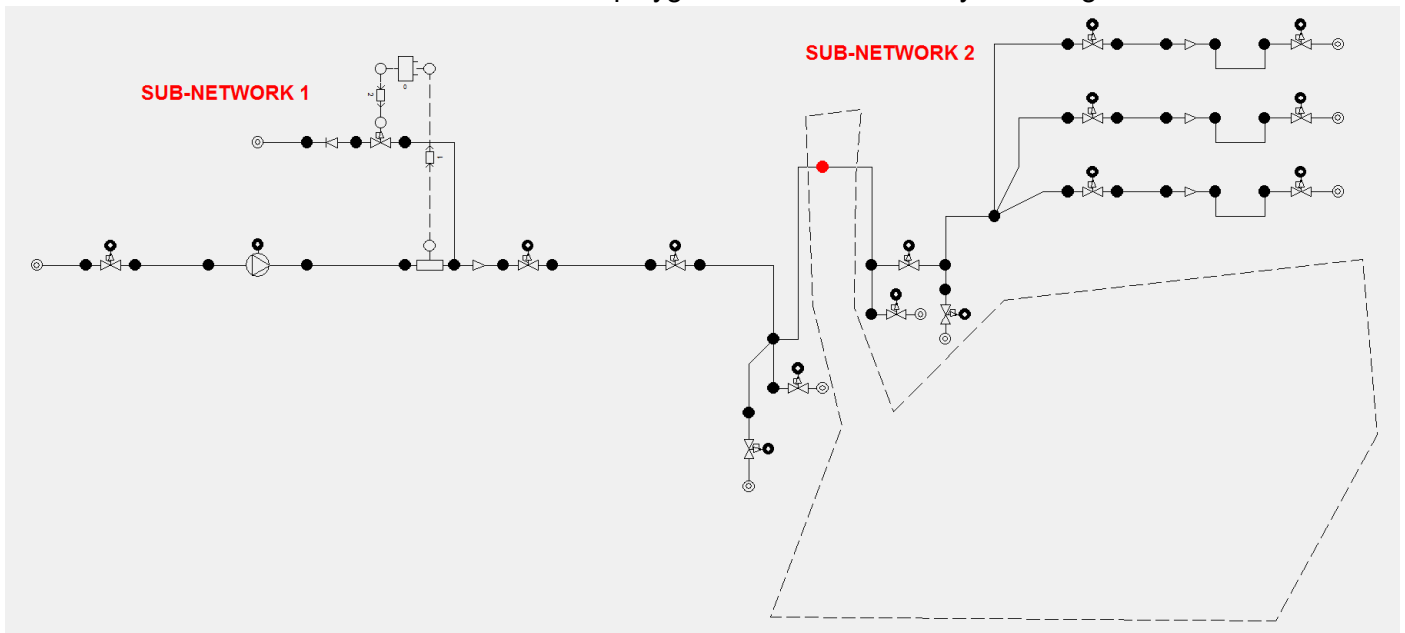
CONCLUSION

We have shown in this article that creating large and complex systems consisting of many subsystems can be done fast and easily in PIPENET. A number of tools are available in PIPENET which allow various manipulations with subnetworks.

How to…?

Convert to Transient

Converting a data file from Standard or Spray/Sprinkler Module to Transient Module is an invaluable function of PIPENET which saves engineers a lot of time and effort.

In order to convert a Standard or Spray/Sprinkler Module file (.SDF) and the associated library file (.SLF) into a Transient Module file, you will need to specify the input file name and the output file name in **Utilities | Convert a Model to Transient**.
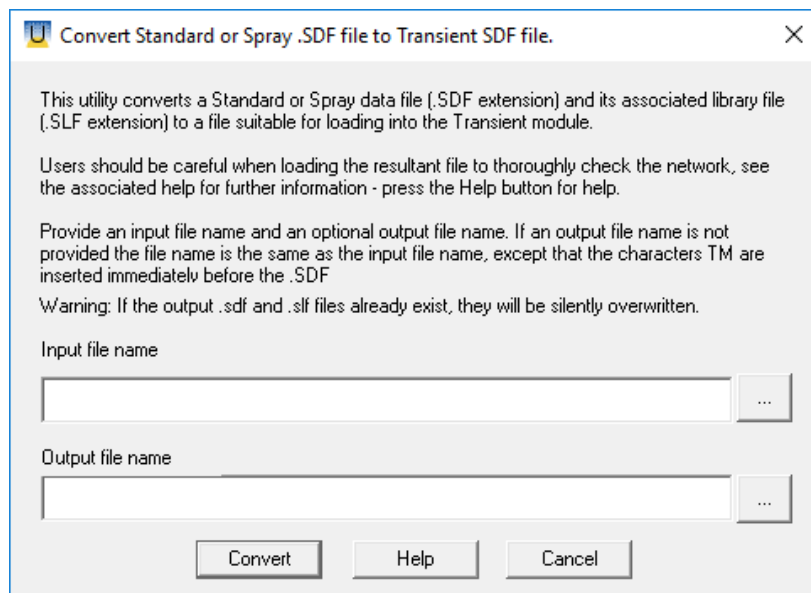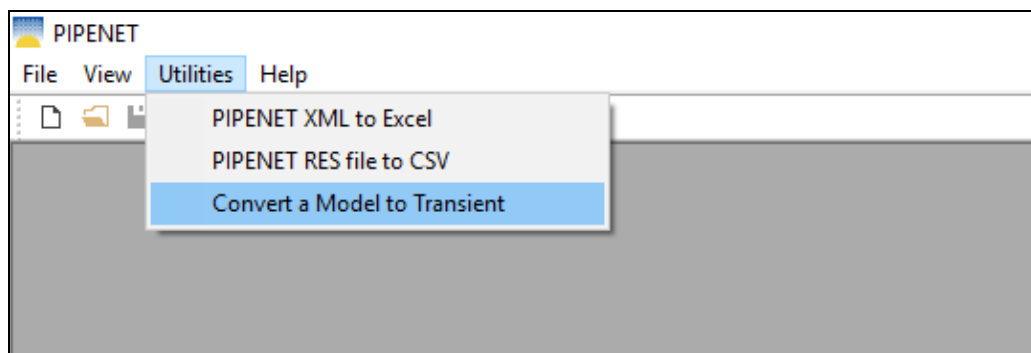
With any model open, you will find this utility in **Tools | Utilities | Convert a Model to Transient**.
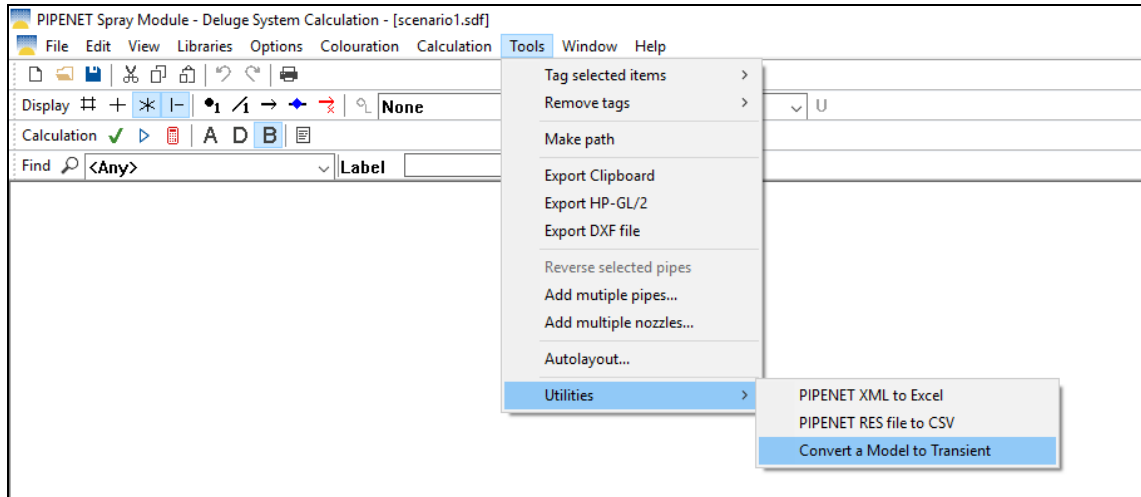
It is important to consider the following observations when converting to Transient:

1. Some components in the Standard or Spray/Sprinkle Module may not have corresponding components in the Transient Module, e.g. elastomeric valve etc. You have to input these components manually after conversion. Also, please use the latest version of PIPENET because it can save you a lot of time. For example, nozzles can be converted after the version 1.8.

2. The Transient Module requires more input data. Therefore, you have to input these absent data after conversion. For example, pipe OD, Young's modulus and Poisson's ratio are required in the Transient Module.

Convert a Pressure Drop into an Equivalent Length

Sometimes an engineer may need to calculate an equivalent length of a device knowing its pressure drop.

Often, the manufacturer will be able to provide an equivalent length for the fitting. However, if this information is not available, there are several ways to calculate it using PIPENET. This operation is most likely to be performed in the PIPENET Spray/Sprinkler Module. Therefore, the examples below are based on Spray/Sprinkler Module calculations.

1. Data:

Let us suppose that we have an item such as a strainer in a fire protection system. The known data is the following:

Diameter = 100 mm nominal size of Schedule 40 pipe

Pressure drop = 0.3 bar

Flowrate = 1000 lit/min

2. A PIPENET Spray/Sprinkler Module calculation using the following data:

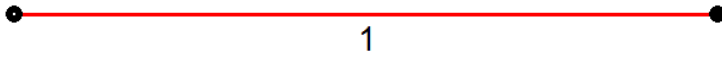Input a pipe with a diameter of 100 mm and length of 100 m.

	Pipe
Label	1
Input node	1
Output node	2
Type	ANSI B36.1...
Diameter	100 mm
Length	100 m
Elevation	0 m
C-factor	120
Status	Normal
Design group	Unset

Set the inlet pressure to 10 barg and the outlet flowrate to 1000 lit/min. Perform a calculation.

SDF1:2

Browse | Analysis spec. | **Print**

D Data | Results | Graphs

	Node	Pressure	Flow
		Bar G	l/min
1	1	10	Unset
2	2	Unset	1000

	Pipe	
Label	1	
Input node	1	
Output node	2	
Type	ANSI B36.1... ▾	
Diameter	100 ▾	mm
Length	100	m
Elevation	0	m
C-factor	120	
Status	Normal ▾	
Design group	Unset	
Results		
Input pressure	10	Bar G
Output pressure	9.501118	Bar G
Friction loss	0.4988825	Bar
Velocity	2	m/sec
Flow rate	1000	l/min
Static head loss	0	Bar

Note that the pressure drop is 0.4988825 bar

3. Calculate the Equivalent Length:

A length of 100 m gives a pressure drop of 0.4988825 bar. So, the length which will give a pressure drop of 0.3 bar is 100 x 0.3 / 0.4988825 = 60.1344 m

4. Alternative Approach:

A simpler method might be to use the general pressure loss model of PIPENET Spray/Sprinkler Module. The dialog box is shown below.
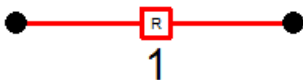
R	General pressure-loss	
Label	1	
Input node	3	
Output node	4	
Type	Constant factor ▾	
Exponent	2	
Reference flow rate	1000	l/min
Reference pressure loss	0.3	Bar
Results		
Input pressure	n/a	
Output pressure	n/a	
Flow rate	n/a	
Pressure drop	n/a	

How to Use Excel for Editing Data in PIPENET

PIPENET provides several means for managing data. Input data can be managed in the properties window or the data window. The properties window can be used to manage data on a particular component, while the data window allows the user to manage data on all components of a certain type at the same time. Copying, pasting and sorting operations can be easily performed in the PIPENET data window. However, some users may feel more confident or find it more convenient to manage data in an Excel spreadsheet. They can use Excel to compare results from different PIPENET simulations. Excel spreadsheets can also be used as part of the report.

This document shows how to use Excel for editing PIPENET data. It is a two-way process where data is copied from PIPENET into Excel, edited in Excel and, if needed, can be pasted back into PIPENET.

If a user would like to take data from PIPENET, edit it in a spreadsheet and use the edited data in PIPENET, the best way would be to use copy and paste as described below. With this approach, it is very important that the format and the order of the rows do not change. In the example below, we use the Pipe data window. The procedure can be used with all data windows.
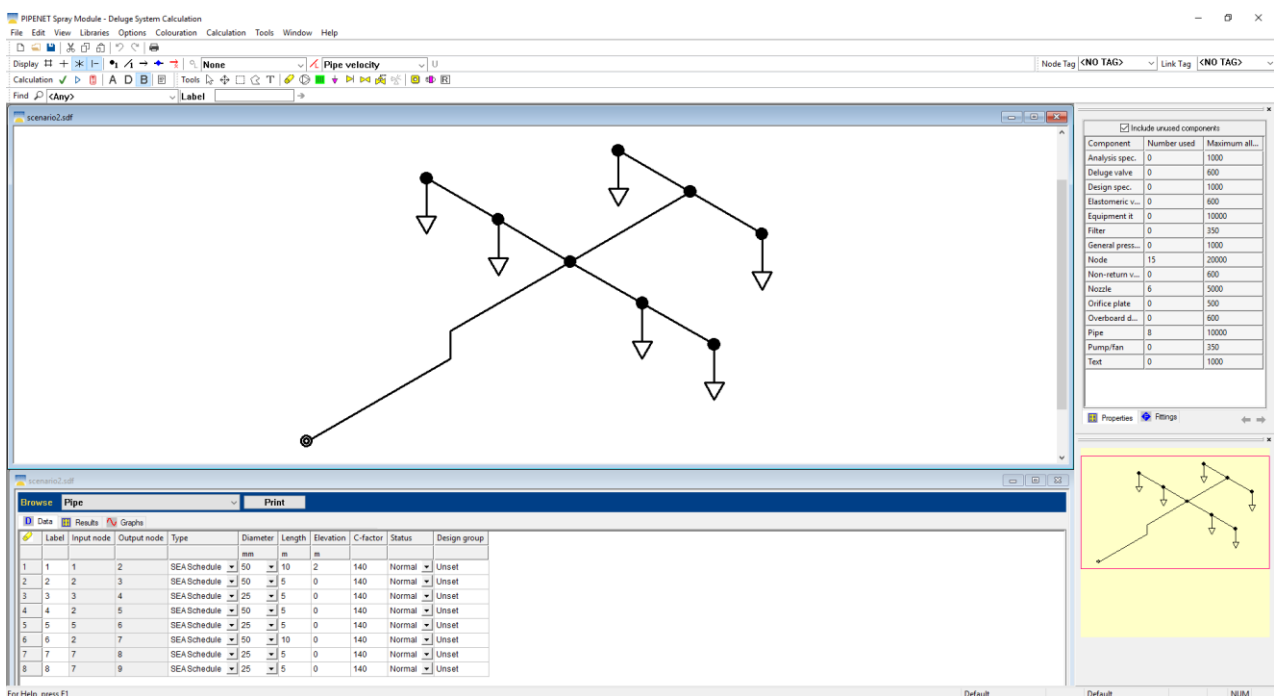
STEP 1: Copy from PIPENET and paste into Excel.

From the PIPENET data window, the full table including headers can be selected by clicking the icon at the top left.
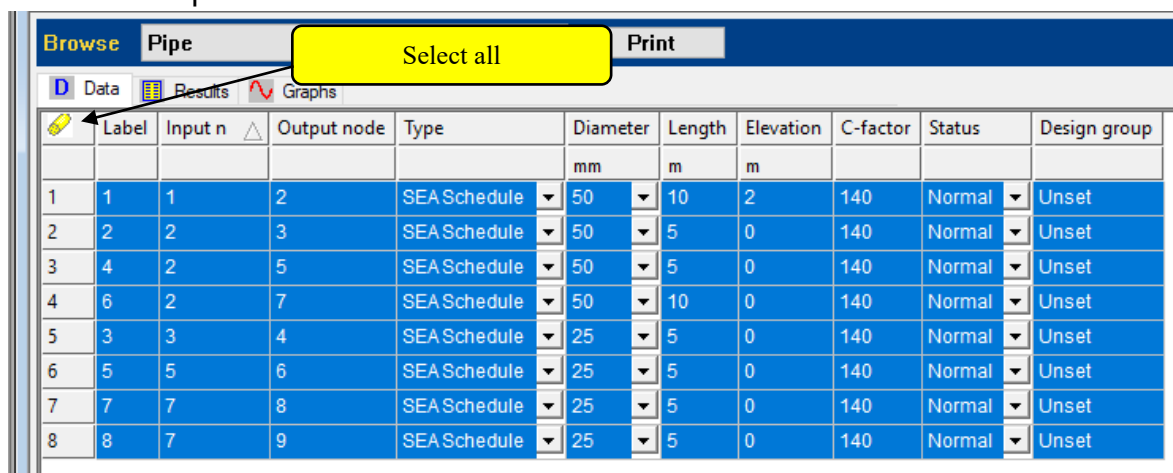
Alternatively, a subset of complete rows can also be edited in this manner as long as the structure is preserved.

This can be copied and pasted directly into Excel.

STEP 2: Pasting edited data from Excel into PIPENET.
Once the data is edited in Excel it can be copied and pasted straight back to the PIPENET data window. To do this, select everything minus the headings in Excel and copy it.

Then in the PIPENET data window click and drag to select the necessary cells and then paste.

The data window should reflect the changes which you made in the Excel spreadsheet:

Caution:

If a pipe diameter which is not included in the schedule is pasted into the data window, it will appear as unset:

	Label	Input node	Output node	Type	Diameter	Length	Elevation	C-factor	Status	Design group
1					mm	m	m			
2										
3	1	1	2	SEA Schedule	90	10	2	140	Blocked	Unset
4	2	2	3	SEA Schedule	90	5	0	140	Normal	Unset
5	4	2	5	SEA Schedule	90	5	0	140	Normal	Unset
6	6	2	7	SEA Schedule	90	10	0	140	Normal	Unset
7	3	3	4	SEA Schedule	25	5	0	140	Normal	Unset
8	5	5	6	SEA Schedule	25	5	0	140	Normal	Unset
9	7	7	8	SEA Schedule	25	5	0	140	Normal	Unset
10	8	7	9	SEA Schedule	25	5	0	140	Normal	Unset

The same rules apply for other parameters selectable via combo box rather than typed.

It is also very important to keep the rows in their original sequence. If the rows are reordered in Excel, the following warning message will be produced when this is pasted back into PIPENET in this format.

Label	Input node	Output node	Type	Diameter	Length	Elevation	C-factor	Status	Design group
				mm	m	m			
2	2	3	SEA Schedule	50	5	0	140	Normal	Unset
1	1	2	SEA Schedule	50	10	2	140	Normal	Unset
4	2	5	SEA Schedule	50	5	0	140	Normal	Unset
6	2	7	SEA Schedule	50	10	0	140	Normal	Unset
3	3	4	SEA Schedule	25	5	0	140	Normal	Unset
5	5	6	SEA Schedule	25	5	0	140	Normal	Unset
7	7	8	SEA Schedule	25	5	0	140	Normal	Unset
8	7	9	SEA Schedule	25	5	0	140	Normal	Unset
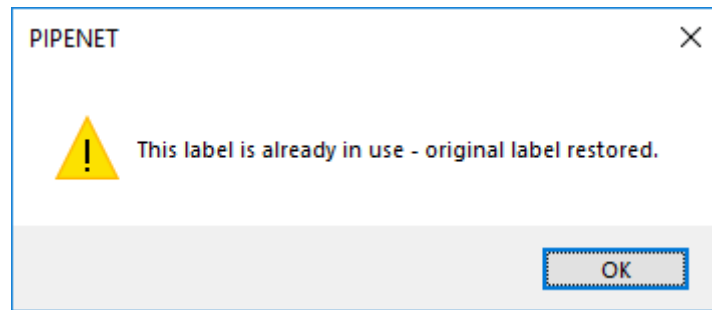
The result of this is the original order of the rows in the PIPENET data window is preserved but the other information is reversed: