PIPENET®

LEADING THE WAY IN FLUID FLOW ANALYSIS

SUNRISE

PIPENET News – Autumn 2020

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PIPENET Transient has had two cavitation models so far - vapour cavitation and channel cavitation. Both the models are based on the assumption of the absence of free gas in liquid systems. However, liquid usually contains a little amount of free gas in many practical physical systems which may produce great impact on wave propagation.

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PIPENET Transient module is successfully used to mitigate potential pressure surges and cavitation in LNG loading systems. A number of scenarios are considered before arriving at the optimum philosophy of operation.

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Surge analysis of the firewater system on an FLNG

In this document we demonstrate some of the capabilities of PIPENET Transient module for performing surge analysis of the firewater system on an FLNG. We also show how it could be used in finding a method of bringing the pressure surge down to an acceptable level.

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Dear PIPENET user!

We hope you are healthy and safe in these uncertain times.

Taking an opportunity, we would like to thank you for being a loyal PIPENET customer. We would also like to assure you that PIPENET team is here, as always, ready to provide excellent support whenever you may need it.

Please do not hesitate to contact us:

for technical support – at

support@sunrise-sys.com

for any other questions – at

pipenet@sunrise-sys.com

We look forward to hearing from you!

Yours faithfully,

PIPENET team

Discrete Gas Cavity Model (DGCM) – new feature in PIPENET Transient module

Introduction

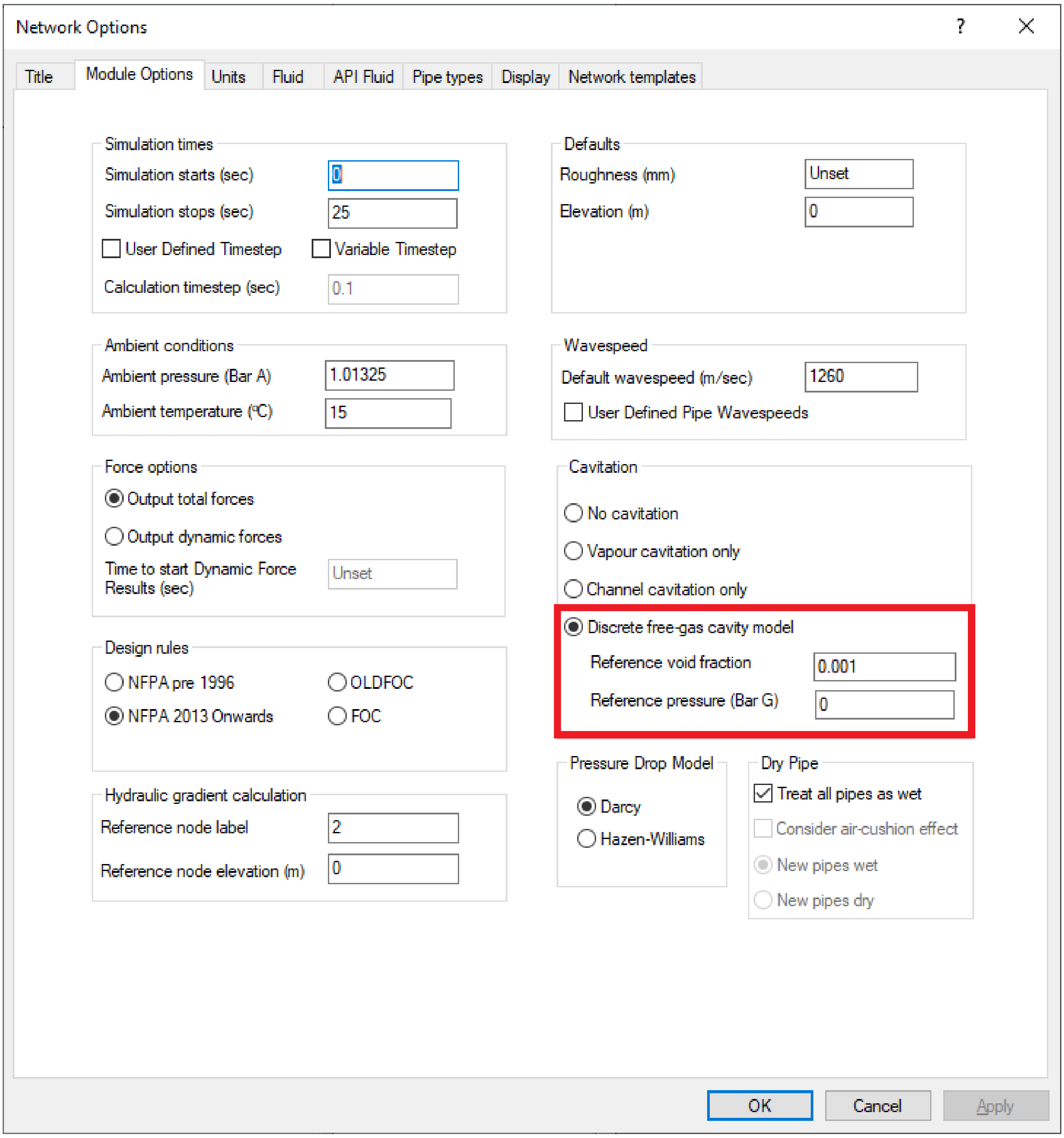
PIPENET Transient Module has developed two cavitation models (vapour cavitation and channel cavitation) for transient phenomena of column separation. Both the models are based on the assumption of the absence of free gas in liquid systems, i.e. single-component two-phase transient flow. However, liquid usually contains a little amount of free gas in many practical physical systems which may produce great impact on wave propagation (speed and magnitude). Wylie and Streeter, who discuss this in the book "Fluid Transients in Systems", state that it is generally assumed that the mass of free gas remains constant at the initial value during a transient event as it is difficult to predict the dynamic value accurately.

This model proposed by Wylie and Streeter to consider the effect of a small quantity of free gas in continuous liquid, i.e. discrete gas cavity model (DGCM), is available in PIPENET Transient module.

Activating DGCM in PIPENET Transient module

The discrete free-gas cavity model (DGCM) can be activated in "Module Options" window. If the cavitation option is "Discrete free-gas cavity model", the reference void fraction and reference pressure are required to calculate gas mass in unit volume liquid. The reference void fraction is the gas volume void fraction at the reference pressure.

The default reference void fraction is 0.001. The reference void fraction must be in the range of 0.0 < VF < 1.0. Otherwise, an error message will be given.
The default reference pressure is 0 Bar G. The reference pressure must be bigger than the vapour pressure. If the vapour pressure exceeds 0 Bar G, the default reference pressure is set as vapour pressure + 1 Bar. Otherwise, an error message will be given.


Network Options
Title
Module Options
Units
Fluid
API Fluid
Pipe types
Display
Network templates
Simulation times
Simulation starts (sec)
0
Simulation stops (sec)
25
User Defined Timestep
Variable Timestep
Calculation timestep (sec)
0.1
Defaults
Roughness (mm)
Unset
Elevation (m)
0
Ambient conditions
Ambient pressure (Bar A)
1.01325
Ambient temperature (°C)
15
Wavespeed
Default wavespeed (m/sec)
1260
User Defined Pipe Wavespeeds
Force options
Output total forces
Output dynamic forces
Time to start Dynamic Force Results (sec)
Unset
Cavitation
No cavitation
Vapour cavitation only
Channel cavitation only
Discrete free-gas cavity model
Reference void fraction
0.001
Reference pressure (Bar G)
0
Design rules
NFPA pre 1996
OLDFOC
NFPA 2013 Onwards
FOC
Pressure Drop Model
Darcy
Hazen-Williams
Dry Pipe
Treat all pipes as wet
Consider air-cushion effect
New pipes wet
New pipes dry
Hydraulic gradient calculation
Reference node label
2
Reference node elevation (m)
0
OK
Cancel
Apply

Modelling LNG Loading Systems

BACKGROUND

In this application bulletin we illustrate the use and benefits of PIPENET Transient module in mitigating potential pressure surges and cavitation in LNG loading systems. A number of scenarios are considered before arriving at the optimum philosophy of operation.
In particular we consider the following two aspects of the normal shut down of the system. The simulations pinpoint the strategy for eliminating pressure surge problems.

1. The pressure surge upstream of the shut off valve.
2. Cavitation in the loading arm.

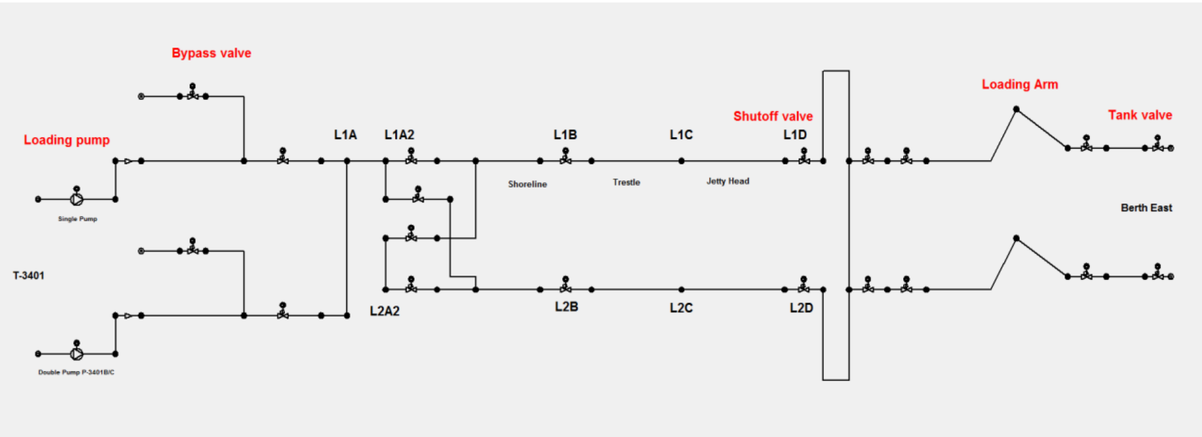
The table below shows the scenarios which were considered. In all cases the shut off valve closes.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Pump stops	No	Yes	Yes	Yes	Yes
Bypass valve opens	No	Yes	Yes	Yes	Yes
Back pressure at tank	No	No	Yes	Yes	Yes
Tank valve closes	No	No	No	Yes	Yes
Higher elevation of loading arm	No	No	No	No	Yes

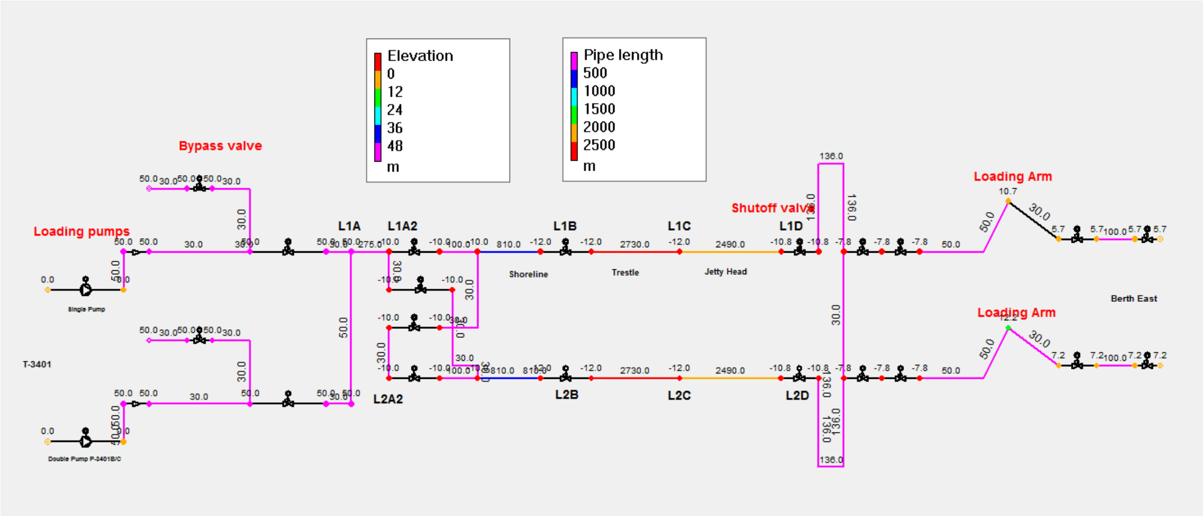
LNG properties:

Density	=	444 kg/m3
Viscosity	=	0.128 cP
Bulk modulus	=	1.17x 10^9 Pa
Vapour pressure	=	0 barg

The apex of the loading arm is 21.5 m above the shut-off valve in Scenarios 1 – 4. In Scenario 5 it is increased to 46.5 m.
The schematic drawing of the network:



The schematic drawing with colour coding:



THE RESULTS

Both graphical and numerical results are presented for the 5 scenarios outlined above.

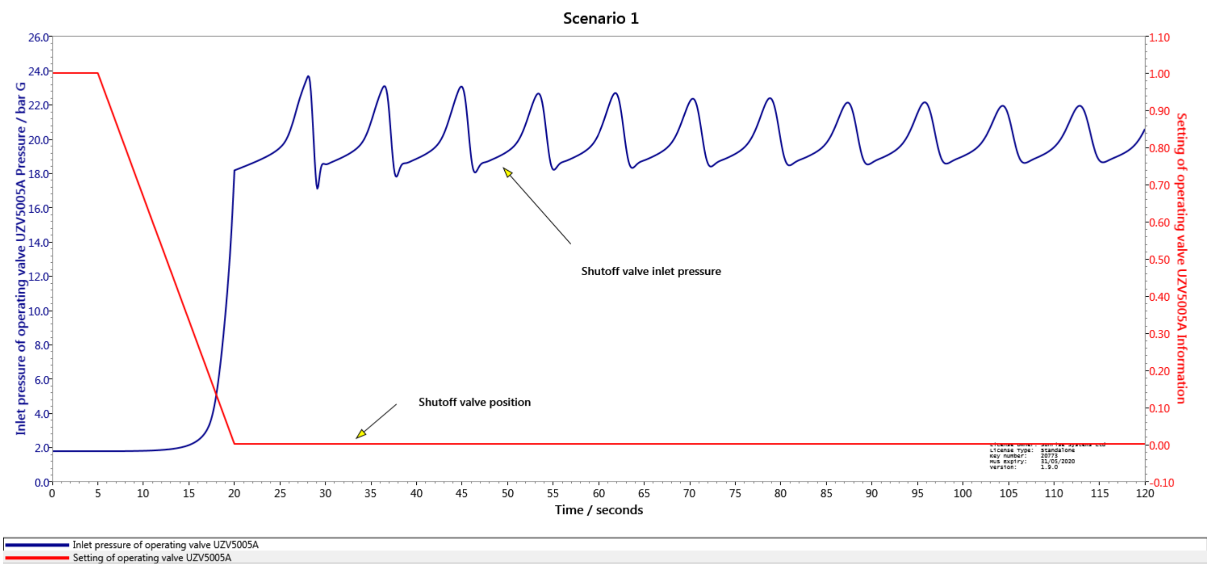
Scenario 1

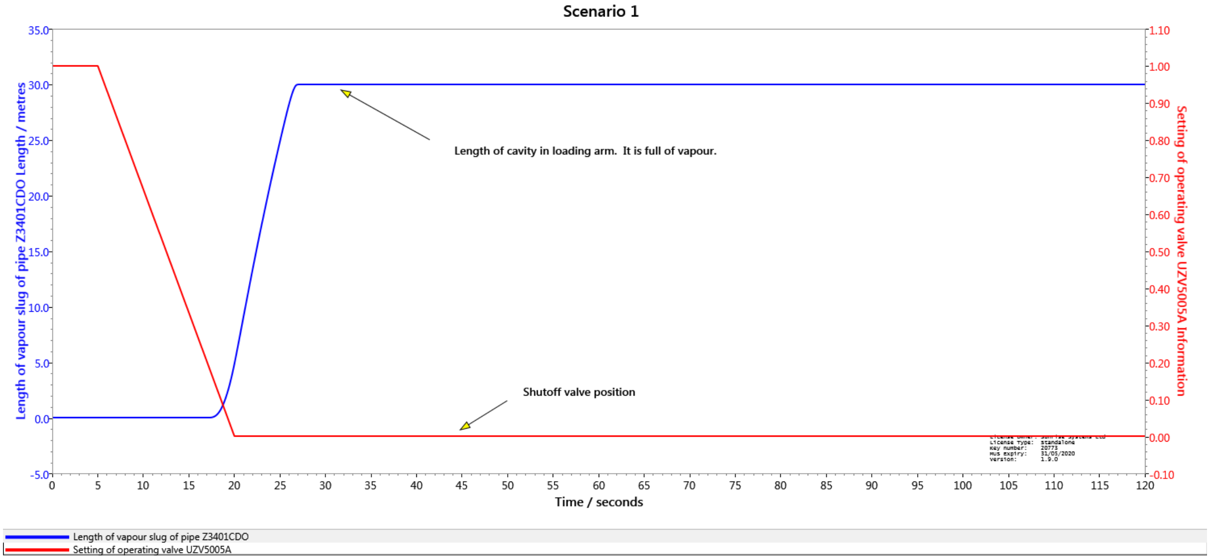
In this scenario the shutoff valve closes and no other transient phenomena take place.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 23.6586 bar G
          on pipe 25 at the outlet
          at time 28.10000 seconds

Minimum pressure is 0.00000 bar G
          on pipe 4 at the inlet
          at time 0.000000 seconds
```





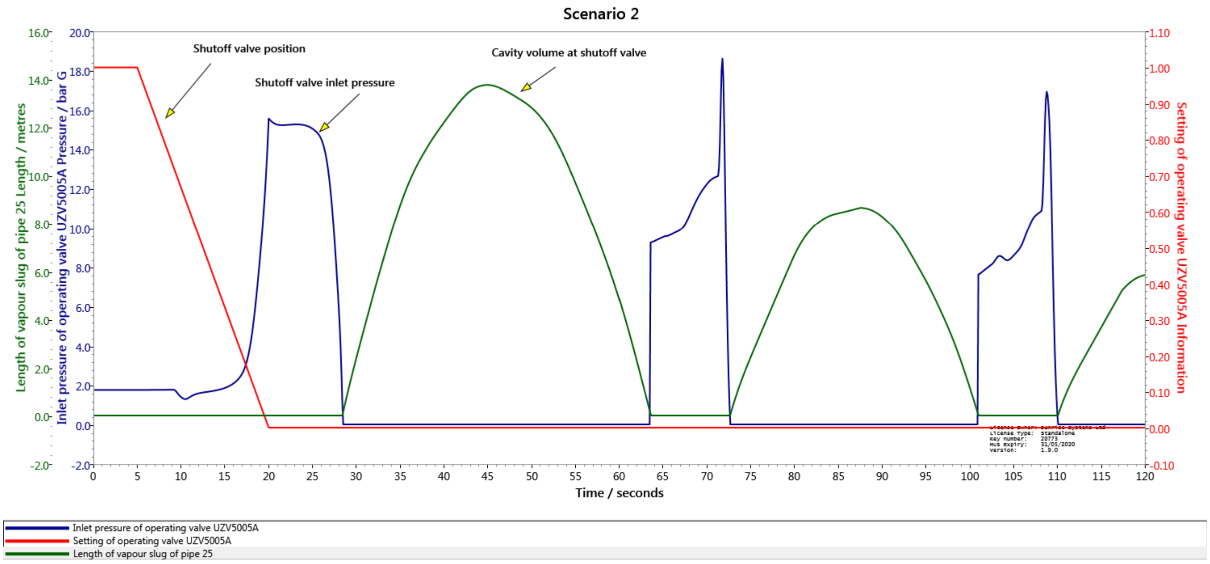
Scenario 2

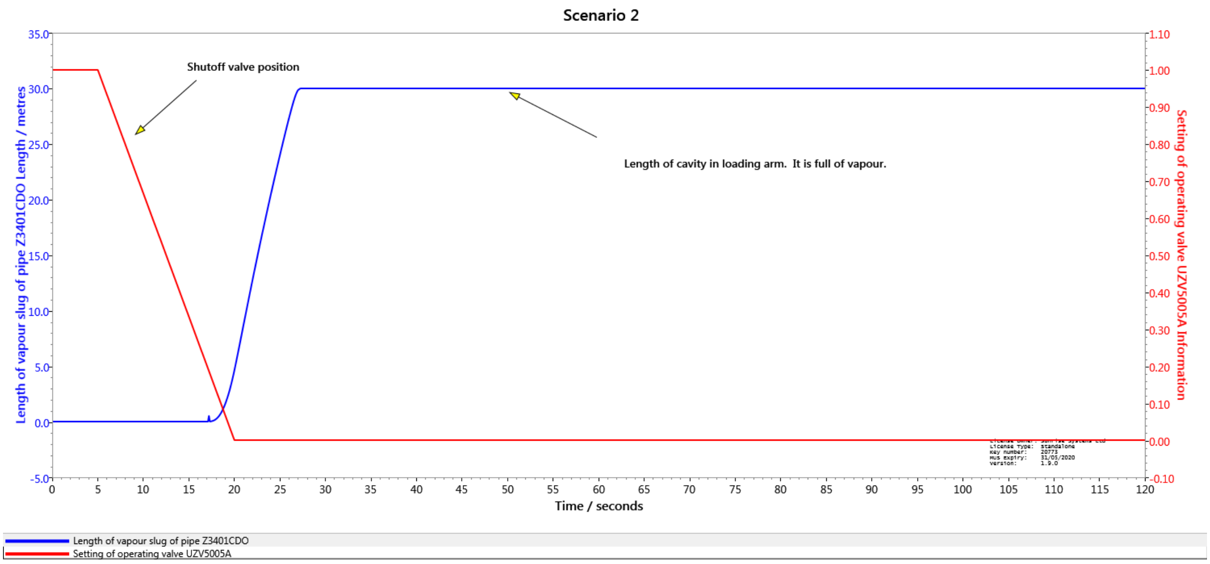
In this scenario the shutoff valve closes, the loading pump stops and the bypass valve opens.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 18.6108 bar G
          on pipe 25 at the outlet
          at time 71.80000 seconds

Minimum pressure is 0.00000 bar G
          on pipe 4 at the inlet
          at time 0.000000 seconds
```





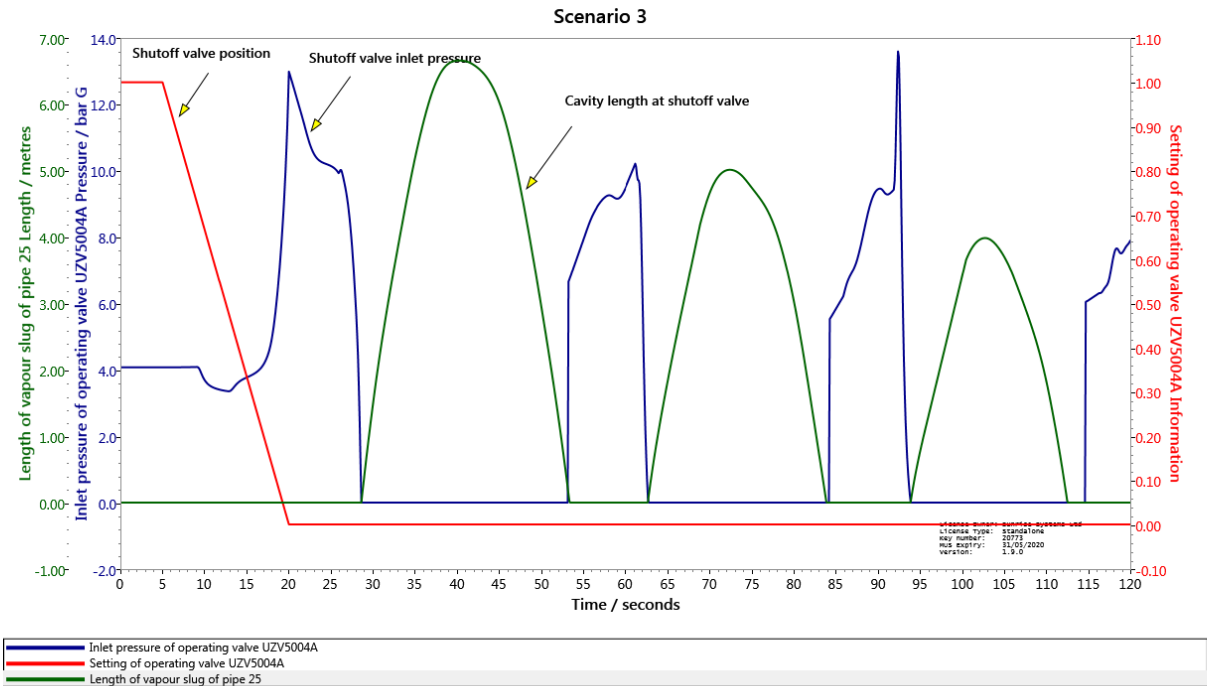
Scenario 3

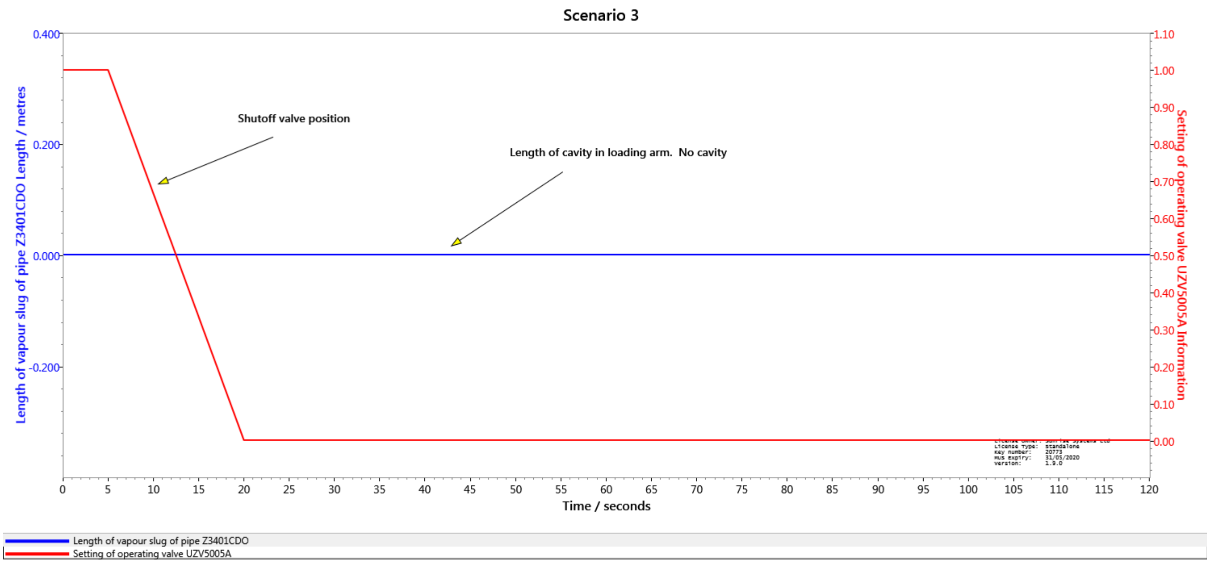
In this scenario the shutoff valve closes, the loading pump stops, the bypass valve opens and the cargo tank has a back pressure of 2.5 barg.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 14.8745 bar G
          on pipe 25 at the outlet
          at time 61.60000 seconds

Minimum pressure is 0.00000 bar G
          on pipe 4 at the inlet
          at time 0.000000 seconds
```





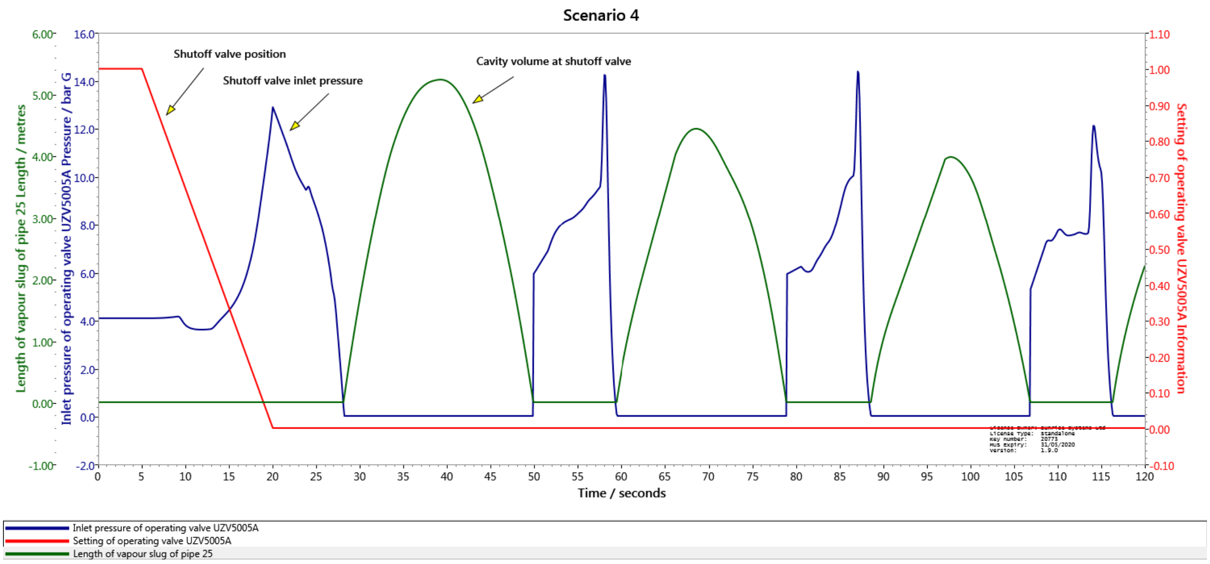
Scenario 4

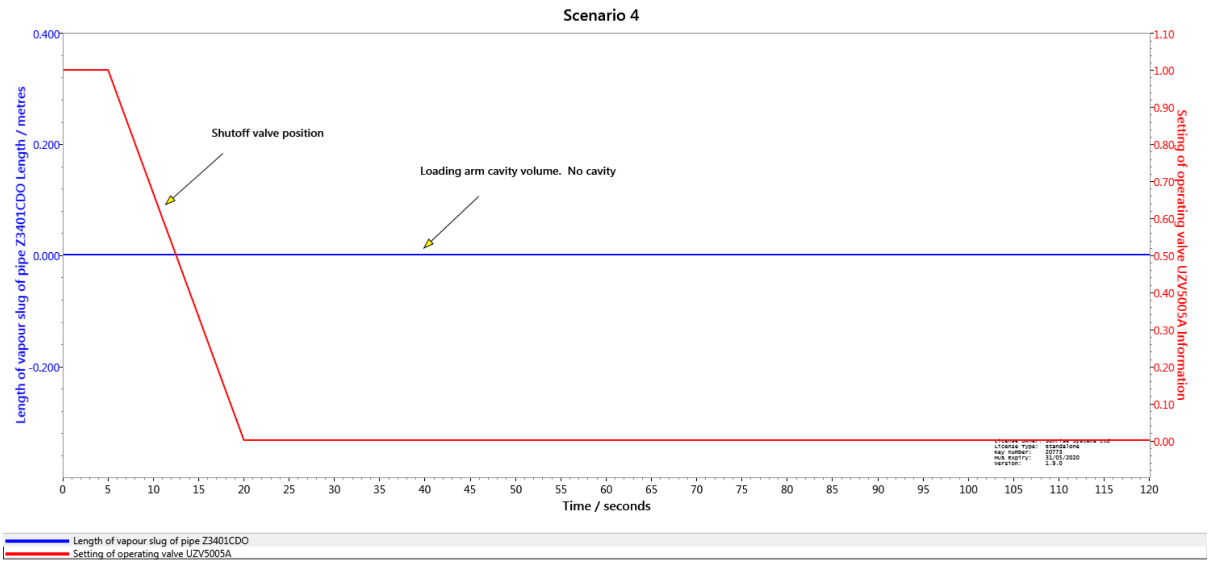
In this scenario the shutoff valve closes, the loading pump stops, the bypass valve opens, the cargo tank has a back pressure of 2.5 barg and the tank valve closes.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 14.3922 bar G
          on pipe 25 at the outlet
          at time 87.10000 seconds

Minimum pressure is 0.00000 bar G
          on pipe 4 at the inlet
          at time 0.000000 seconds
```





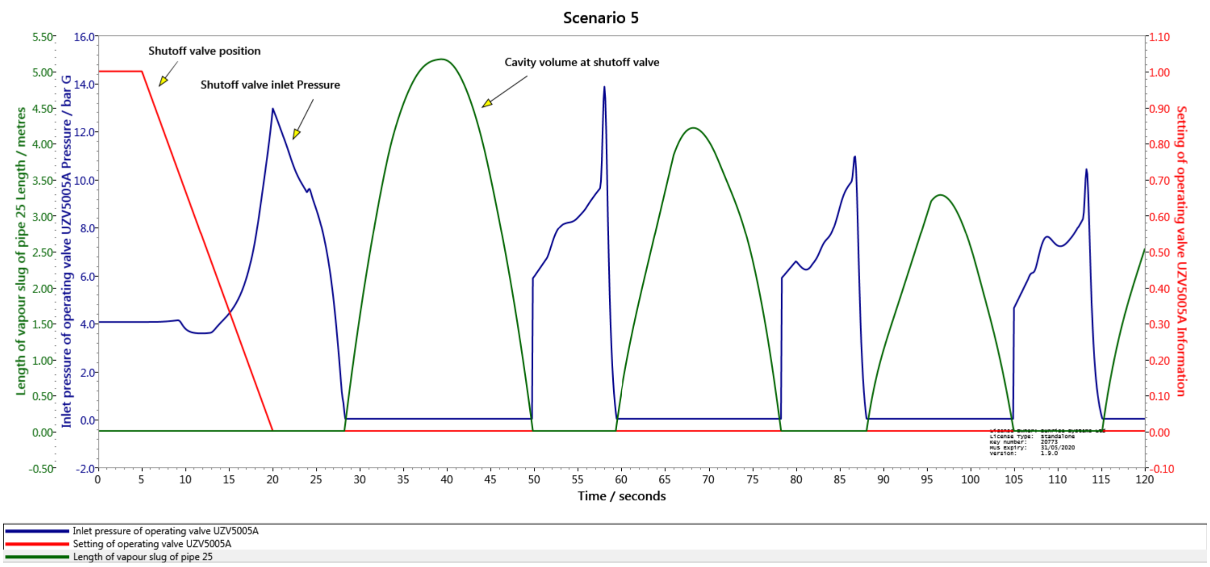
Scenario 5

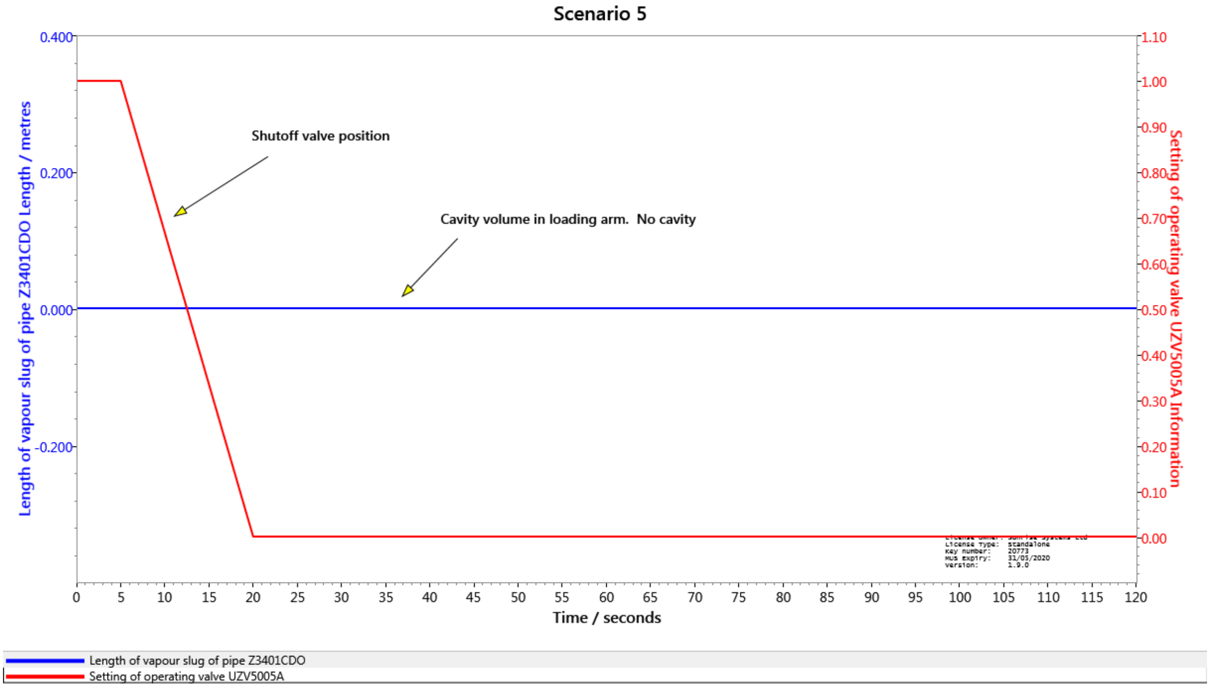
In this scenario the shutoff valve closes, the loading pump stops, the bypass valve opens, the cargo tank has a back pressure of 2.5 barg, the tank valve closes and the apex of the loading arm is increased to 46.5 m above the shutoff valve.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 13.8637 bar G
         on pipe 25 at the outlet
         at time 58.00000 seconds

Minimum pressure is 0.00000 bar G
         on pipe 4 at the inlet
         at time 0.000000 seconds
```





CONCLUSIONS

This document shows why it is essential to perform pressure surge analysis when designing LNG loading systems. The simulations suggest that it is important to shut down the loading pumps and open the bypass valves. It is also important to have a back pressure at the end of the system. However, depending on the design and layout of the system it may be necessary to take other surge alleviating measures.
On the basis that the maximum allowable pressure in the systems is 15 barg, the following table summarises the results of the simulation.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Maximum pressure	23.66 barg	18.61 barg	14.87 barg	14.39 barg	13.86 barg
Acceptability	Not acceptable	Not acceptable	Acceptable	Acceptable	Acceptable

If you have any questions about this case study, or any other of PIPENET's capabilities, please email us at pipenet@sunrise-sys.com.

Surge Analysis of the Firewater System on an FLNG

BACKGROUND

This PIPENET Transient module Application Bulletin shows its use in performing surge analysis of the firewater system on the FLNG development in Africa. The FLNG facility will be a turret moored double-hull floating vessel, on which gas receiving, processing, liquefaction, and offloading facilities will be mounted together with LNG and condensate storage.

The purpose of this document is to show some of the capabilities of PIPENET Transient module for performing surge analysis of the firewater system on the FLNG. The document also shows how PIPENET Transient module could be used in finding a method of bringing the pressure surge down to an acceptable level.

The firewater system on this FLNG had a number of high points for the purpose of supplying hydrants. The scenario which is being considered is the deluge system start up. It is assumed that the hydrants at the high points may be treated as dead ends. This makes the system susceptible to cavity formation. When cavities collapse the result could be very high pressure surges.

Two cases are considered and a method of eliminating the high pressure surge is pinpointed.

Case 1: This is the basic system without the installation of surge alleviation devices.

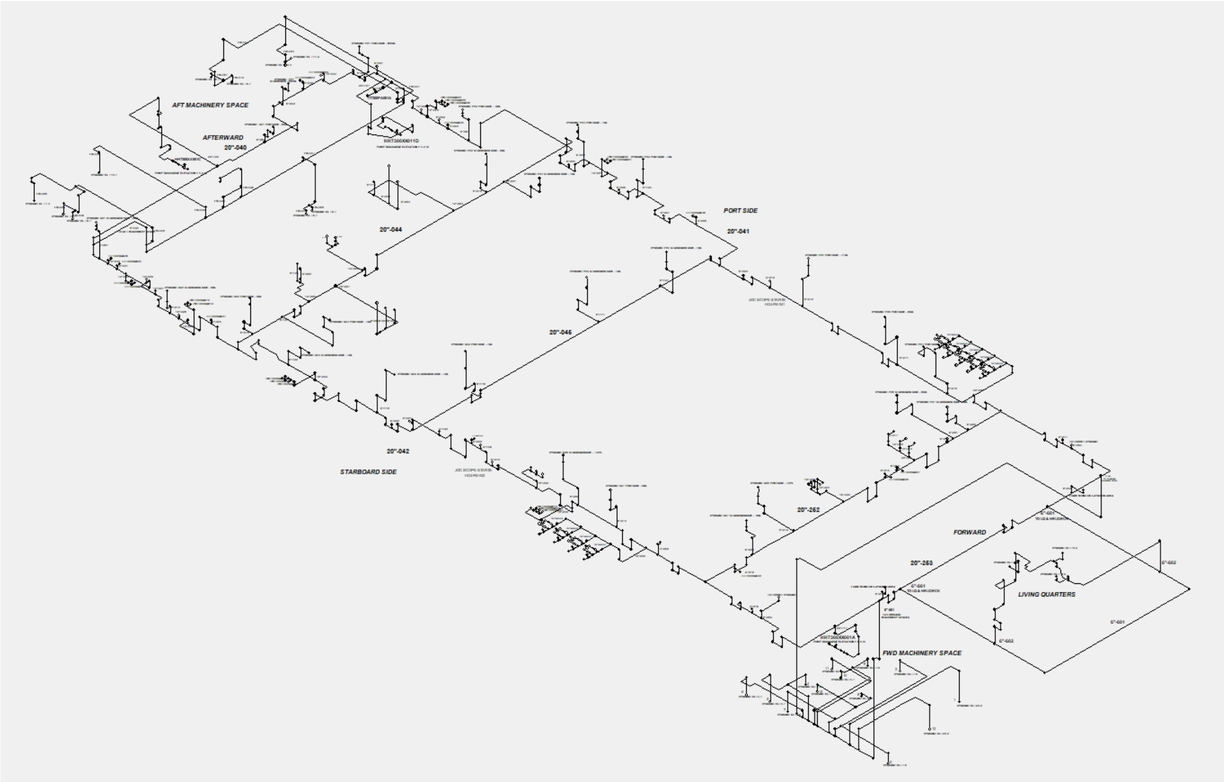
Case 2: One standard method of reducing pressure surges in firewater systems is the installation of vacuum breaker/air released valve. In this case 17 vacuum breakers are assumed to be installed.

1. The Scenario

The firewater system has one forward fire pump and two aft fire pumps. The scenario which is being considered in this bulletin is the maximum forward firewater demand. In this scenario 10 deluge systems start, 5 on the port side and 5 on the starboard side. One of aft pumps starts at 5 secs and runs up in 7 secs. The forward pump starts at 10 secs and runs up in 7 secs. The deluge valves which operate are of the elastomeric type which is intended to maintain the inlet pressure at the deluge system. It is assumed that the deluge systems start operating at 5 secs and it takes 15 secs for the systems to reach full flow.

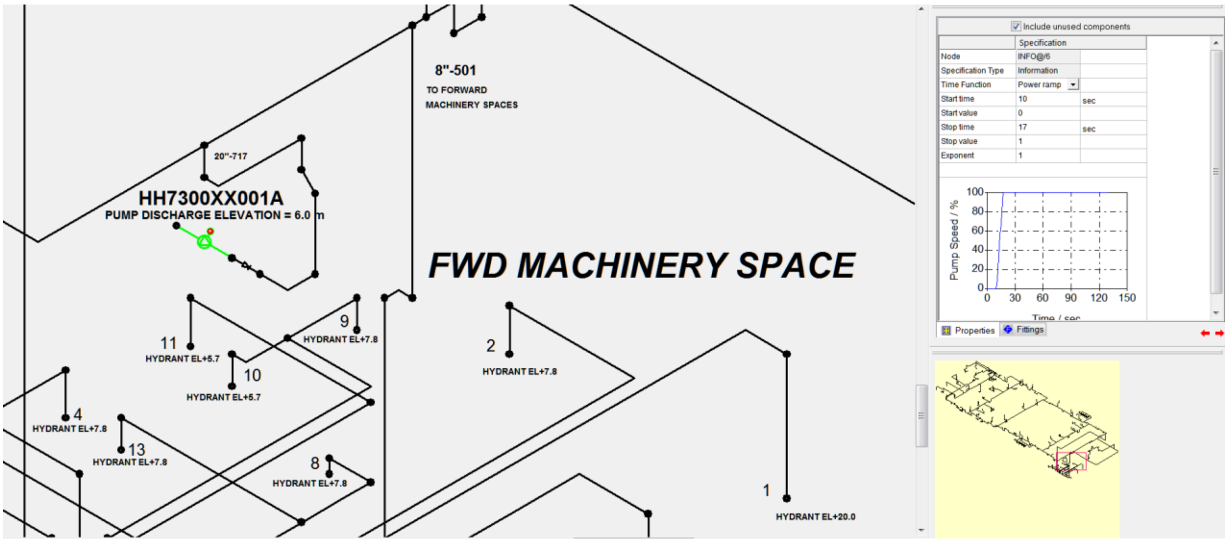
PIPENET Transient module can be used for calculating the deluge system filling time accurately but that is not considered in this Application Bulletin.

2. The Network



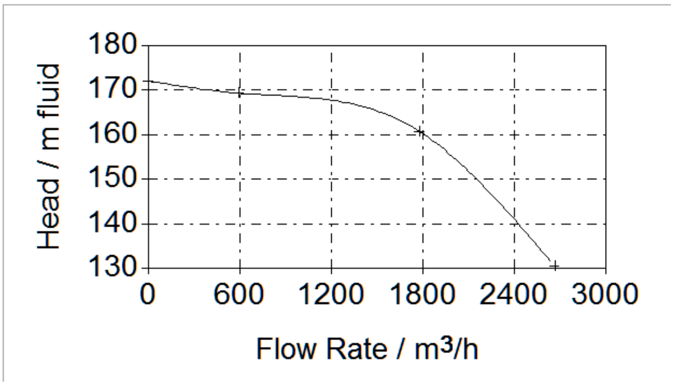
3. Salient Features of the System

3.1. Forward fire pump starts at 10 secs and runs up in 7 secs. The inlet pressure of the pump is constant at 0.46 barg.

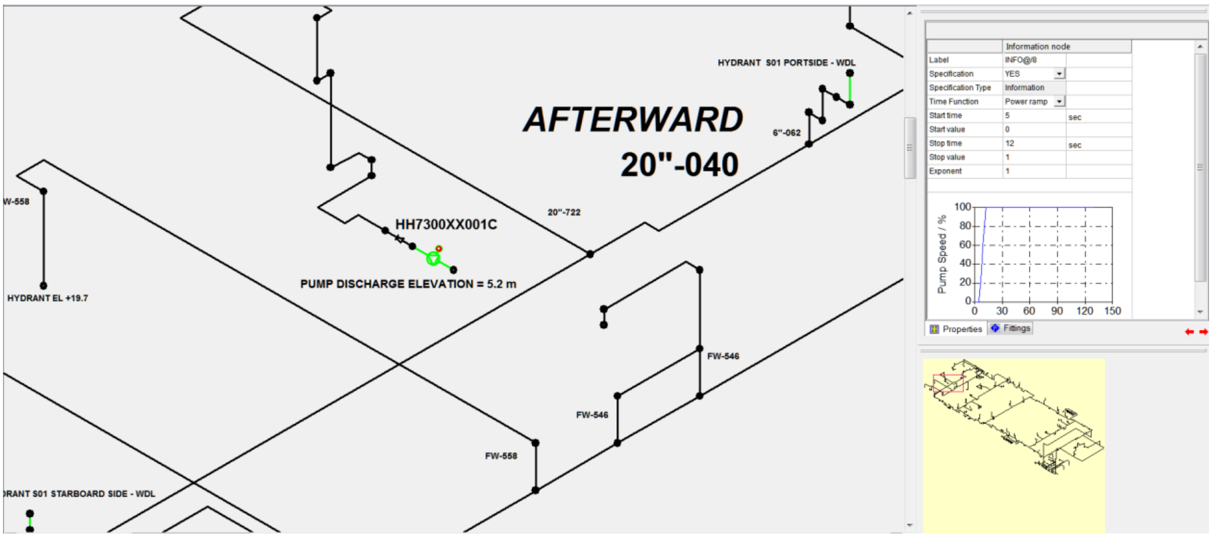


This forward pump has the following performance curve.

Flow rate	Head (input)	Head (curve)	Head (calculation)
m³/h	m	m	m
0	172	172	172
589.1	169.3	169.3	169.3
1777	160.7	160.7	160.7
2665.5	130.6	130.6	130.6

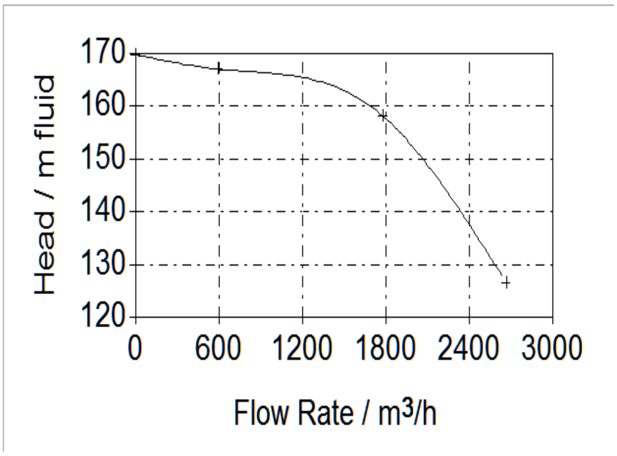


3.2. One of the two aft pumps starts at 5 secs and runs up in 7 secs. The inlet pressure of the pump is constant at 0.55 barg.



This aft pump has the following performance curve.

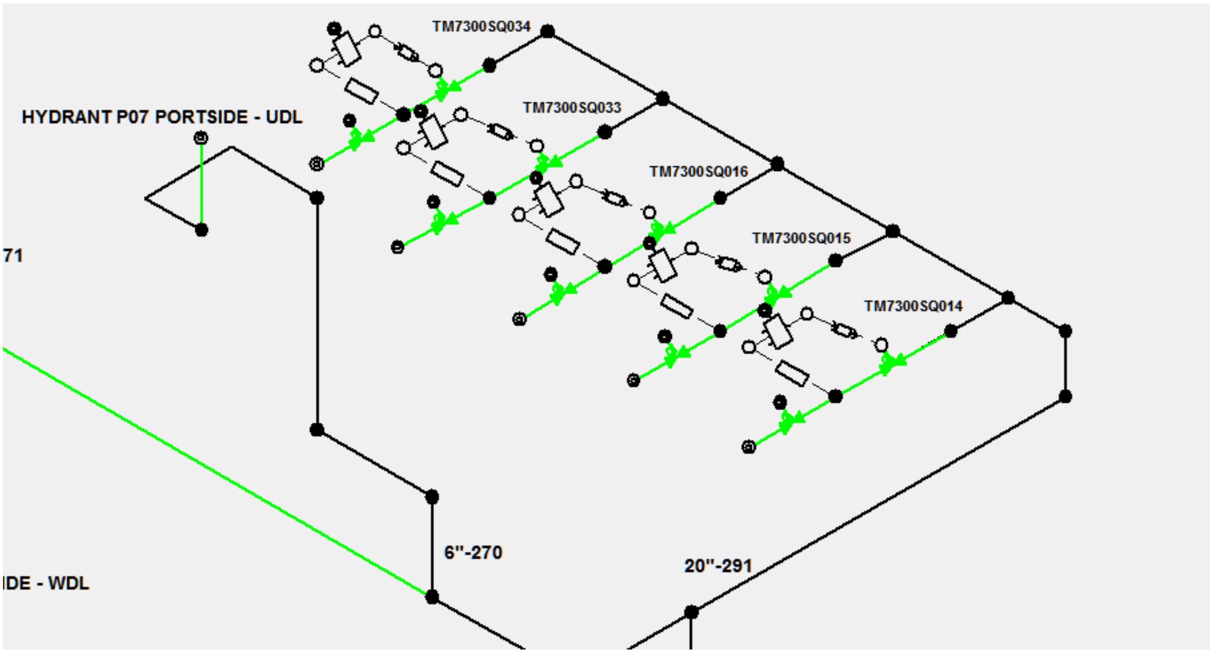
Flow rate	Head (input)	Head (curve)	Head (calculation)
m³/h	m	m	m
0	169.7	169.7	169.7
589.1	167	167	167
1777	158.1	158.1	158.1
2665.5	126.7	126.7	126.7



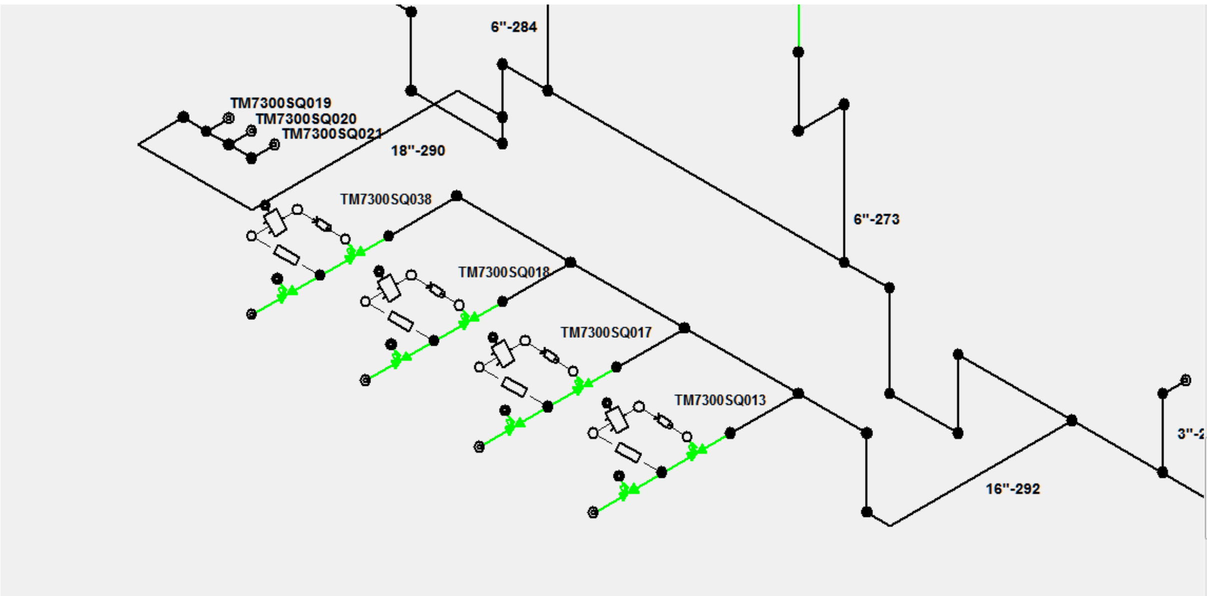
3.3. Deluge Systems:

There are different ways of modelling deluge valves. This model uses a pressure sensor, cascade PID controller and a transfer function.

Deluge Systems on the port side



Deluge Systems on the starboard side



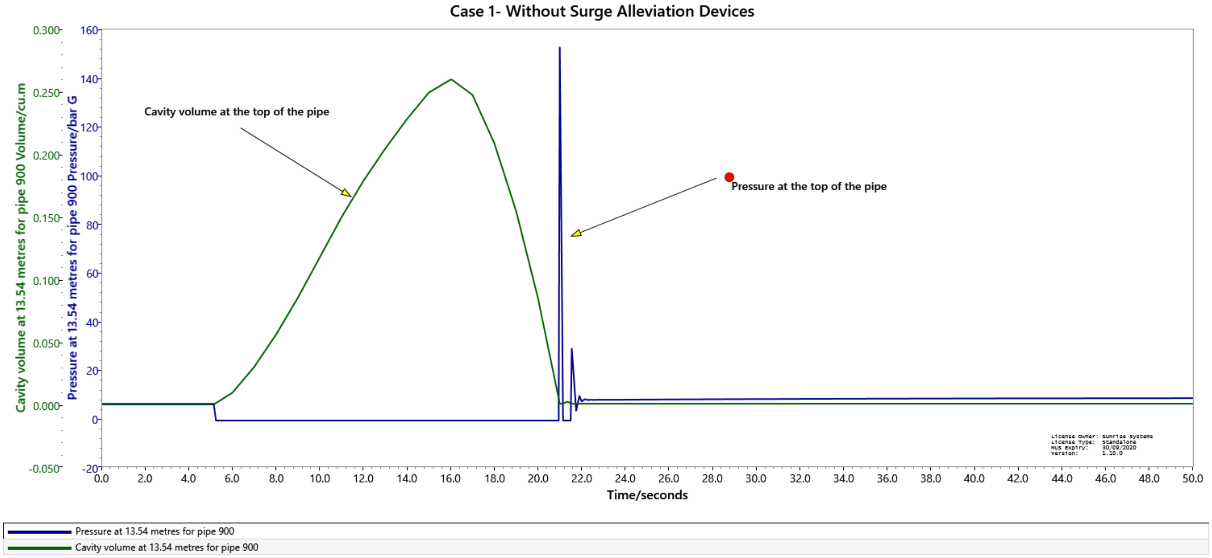
4. Simulation Results:

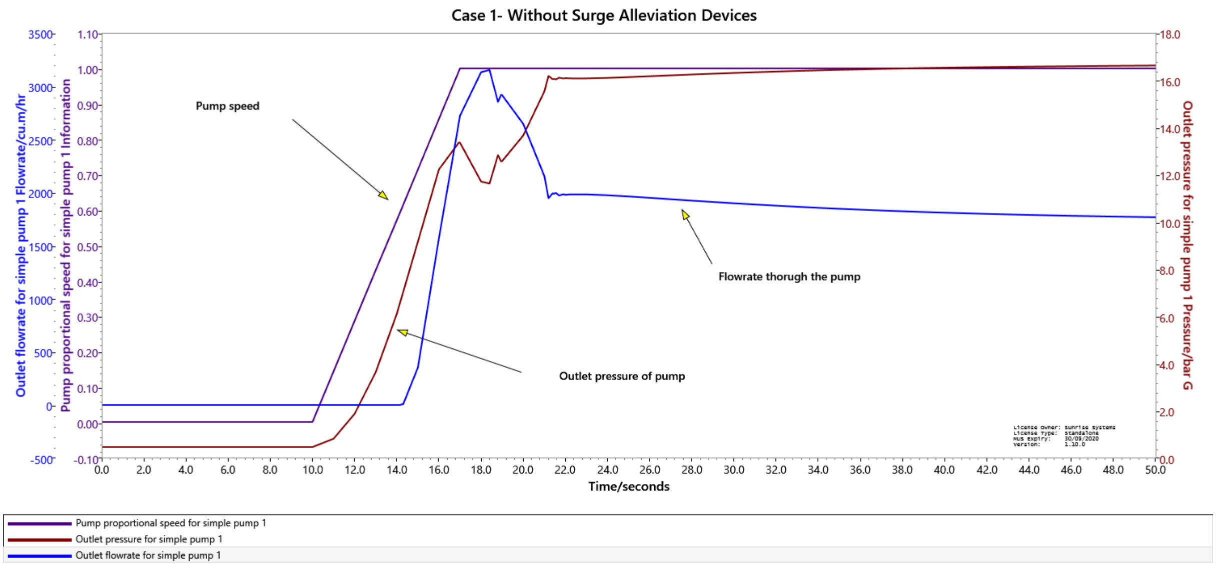
Case 1: The basic system without the installation of surge alleviation devices.

```
PRESSURE EXTREMA
----------------

Maximum pressure is 152.309 bar G
          on pipe 900 at the outlet
          at time 21.00000 seconds

Minimum pressure is -0.971250 bar G
          on pipe 845 at the outlet
          at time 5.200000 seconds
```

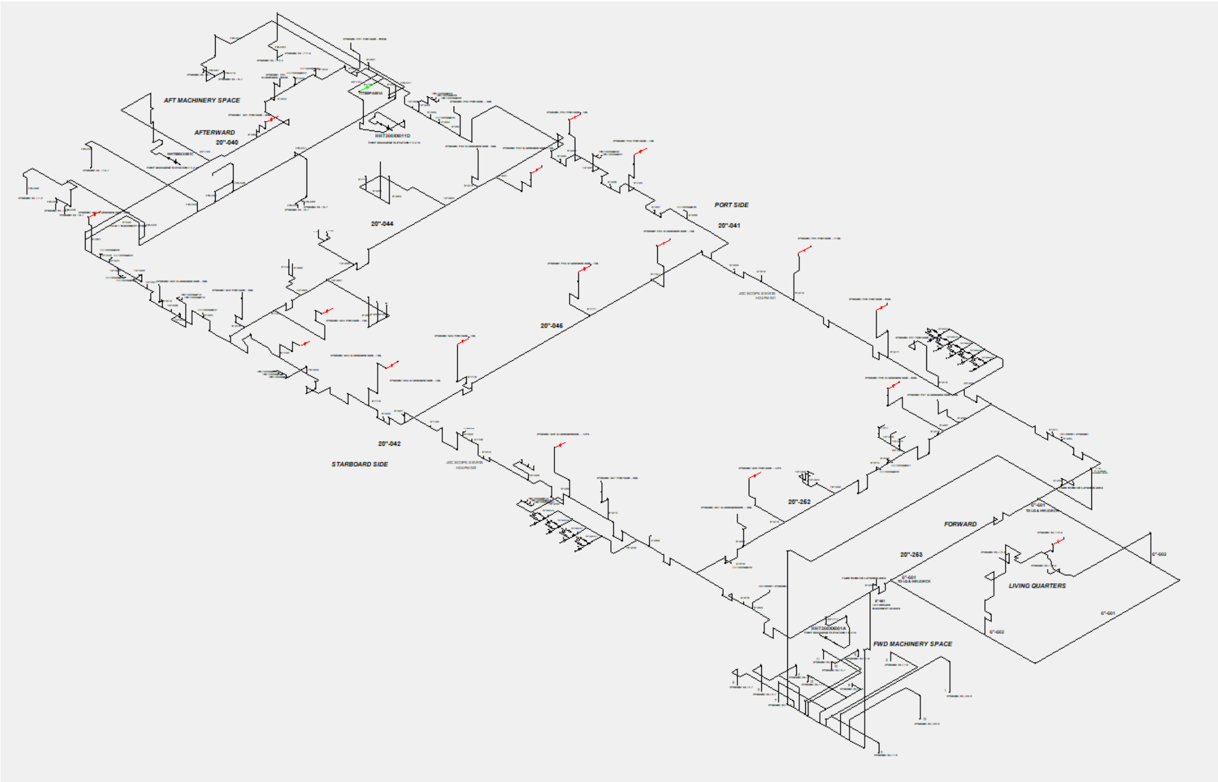




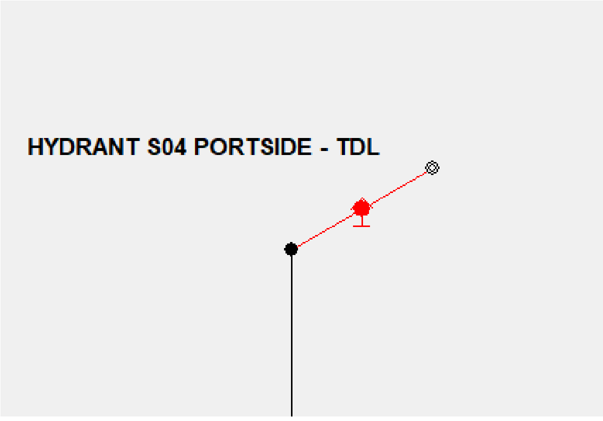
Case 2 – Install Vacuum Breakers at High Points in the System

A total of 17 vacuum breakers were installed. The air inlet was 50 mm and the air outlet was 5 mm. The firewater network had vacuum breakers at high points. In this scenario deluge system start up is being considered. For that reason, hydrants at high levels were considered to be dead ends. A vacuum breaker was installed at every such dead end which was more than 25 m above the datum.

The vacuum breakers are shown in the following schematic in red. They can be seen more clearly by zooming in to 200% magnification.



A typical vacuum breaker and its attributes are shown in the graphic below.

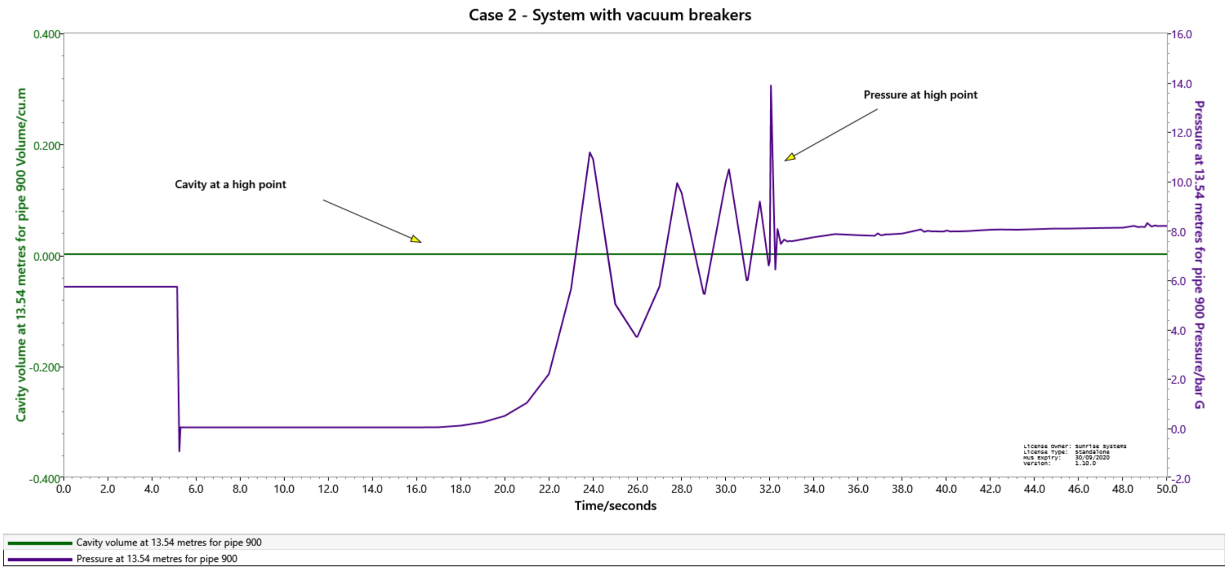


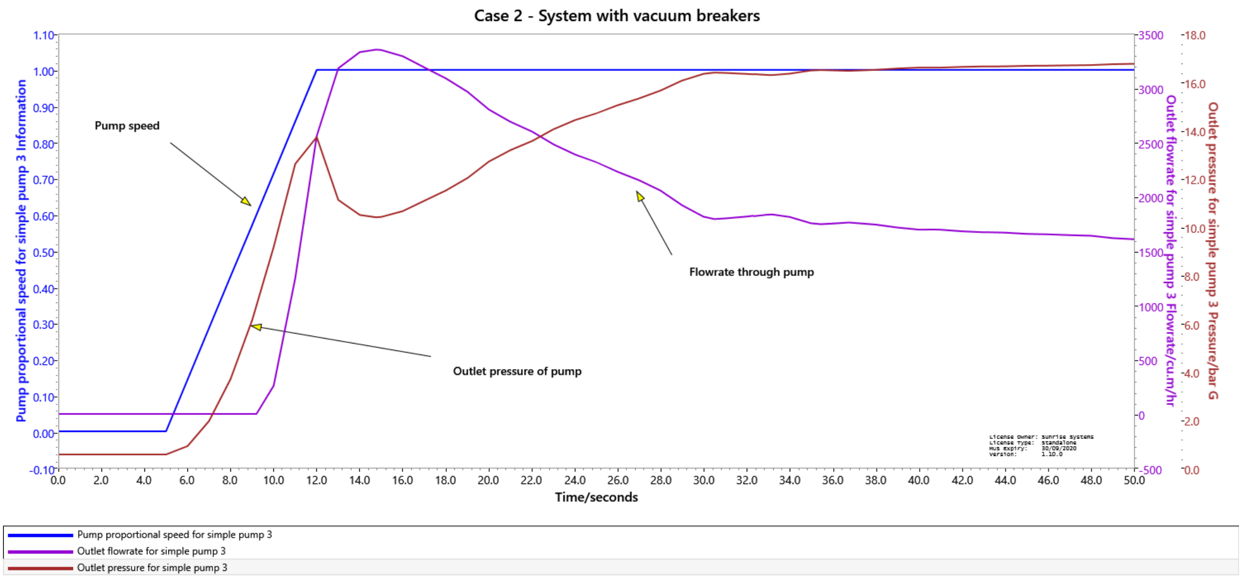
	Vacuum breaker	
Label	8	
Input node	277	
Output node	541	
Inlet Valve Diameter	50	mm
Inlet coeff. of discharge	1	
Set pressure of air inlet	0	Bar G
Outlet Valve Diameter	5	mm
Outlet coeff. of discharge	1	
Set pressure of air outlet	0	Bar G
Valve type	Standard ty...	
Results selected?	NO	

```
PRESSURE EXTREMA
----------------

Maximum pressure is 19.3427 bar G
          on pipe 845 at the outlet
          at time 5.200000 seconds

Minimum pressure is -0.971250 bar G
          on pipe 875 at the outlet
          at time 5.250000 seconds
```





5. Conclusion:

The simulation results show that cavitation is likely unless surge alleviation devices are installed. Cavitation is likely at the high points of the system. The potential pressure surge is around 152.3 barg. By installing 17 vacuum breakers at the high points cavitation is eliminated and the pressure surge comes down to 19.3 barg

If you have any questions about this case study, or any other of PIPENET's capabilities, please email us at pipenet@sunrise-sys.com.

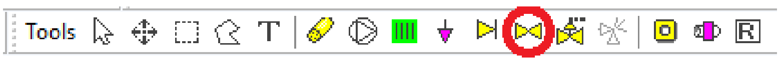
How to…?

How to model deluge valves in Spray/Sprinkler module

There may be cases when the manufacturer gives a Cv value for the valve and an engineer needs to convert it to a K-Factor in order to model it in PIPENET Spray/Sprinkler module.

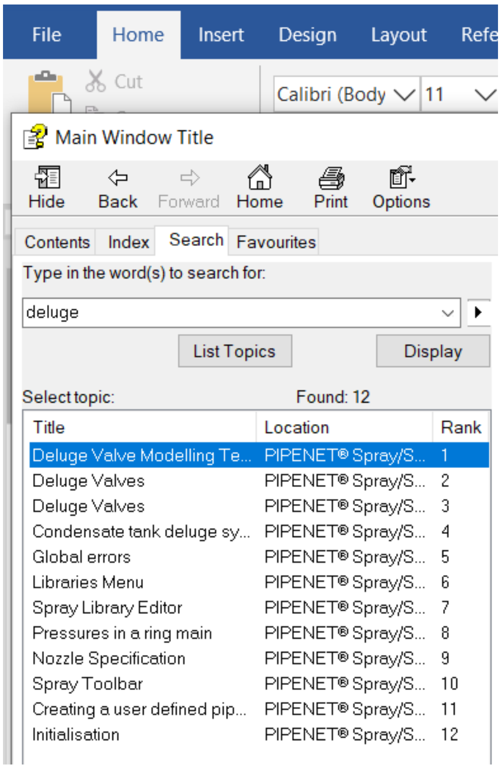
There are different ways of modelling deluge valves in PIPENET Spray/Sprinkler module.

METHOD 1: Use the deluge valve model in PIPENET.



Using this model will require the input of the K-factor and X-factor, where *X* is a constant for the valve (typical values are 1 or 2). It is worth mentioning that this model is present in PIPENET largely for historical reasons. Other models are more commonly used today.

Assuming that we set X = 2, the conversion of C_v to K is quite simple. The below is extracted from the 'Help Text' of PIPENET:



Comparing this equation and the equation for the deluge valve, we can get

$$X = 2$$

and

$$K = Cv^2/G$$

where:

G is the specific gravity of fluid (1 for standard water)

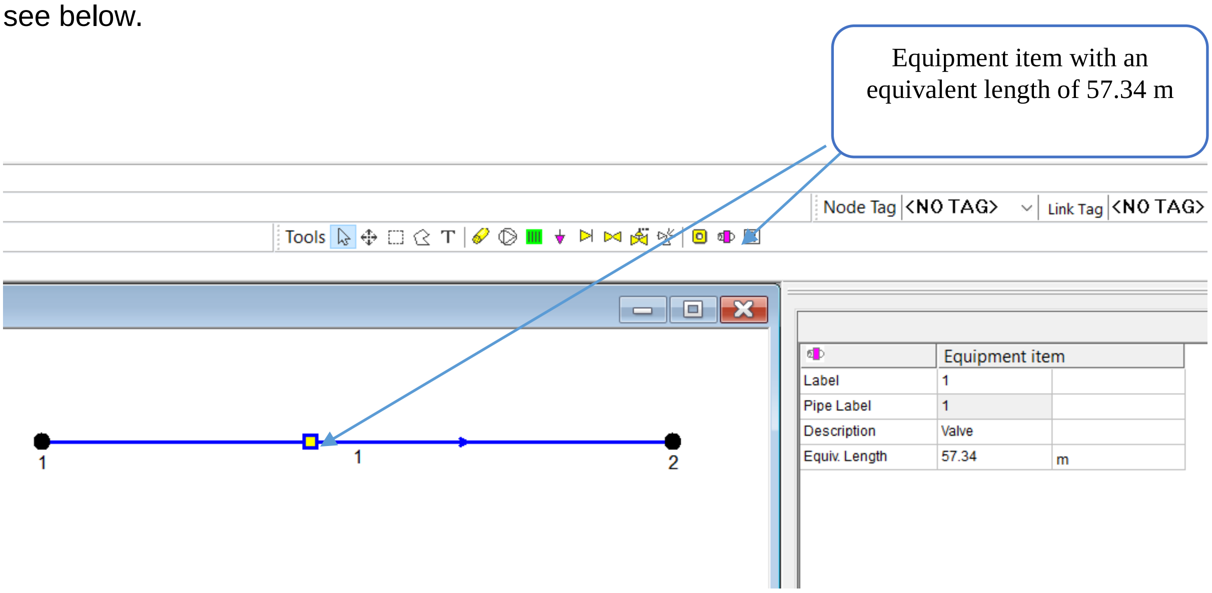
So, essentially

$$K = Cv^2$$

If we set X = 2.

METHOD 2: Replacing the deluge valve by its equivalent length

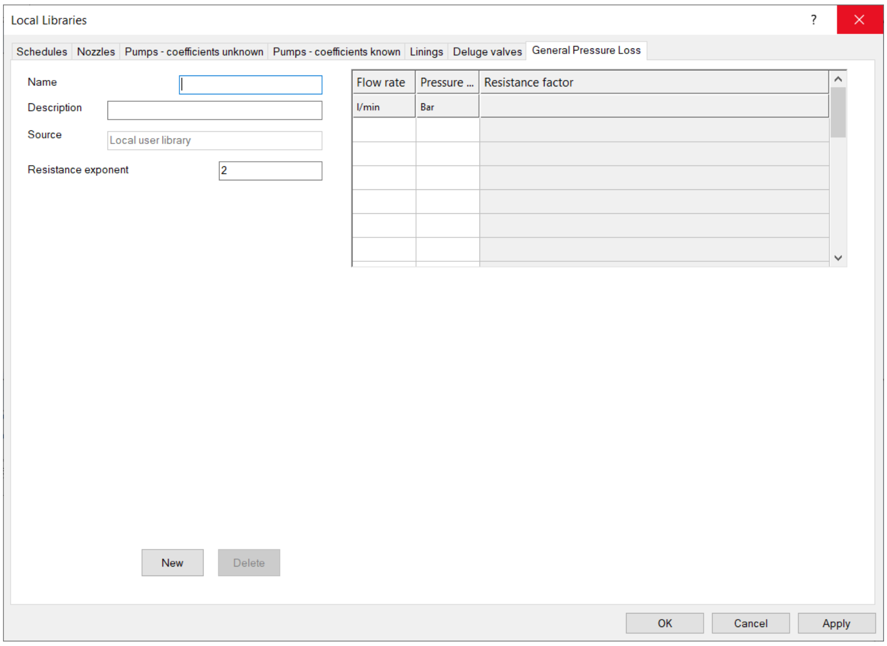
You can replace the deluge valve by its equivalent length. This is probably the most commonly used method. You can add an ‘Equipment item’ to a pipe and set its equivalent length. Please see below.



METHOD 3: Using a general pressure loss component

This can be used if the pressure drop against the flowrate is known as a table or a graph.
You can set up a general pressure loss component in the library and use it in the network. The pressure losses at different flowrates are entered into a table. It can also be entered directly as the pressure loss at a known flowrate and also the power (usually 2).

General Pressure Loss Component entered into a library:



Pressure loss at a known flowrate: