



Pipe2018 Examples Manual

Demonstration Examples

Class Exercises

Training Exercises

Case Studies

Campus Facilities

New Surge Demo Files

October 2015

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How to Use the Examples Manual

This manual is an excellent resource for a wide range of modeling activities. There are examples for absolute beginners (see Section 2 – Class Exercise 1 – QuickStart Example), for design scenarios (Section 3 – Training Exercises – Pumping Stations and Pumping Costs), for special applications (See Campus Facilities), and for a wide range of transient scenarios (See Section 1 – Surge Demonstrations).

Each example narrative is accompanied by a pre-prepared model file. The names of the files are noted in each section. The model files are located in the default file folders installed with the software. A folder exists for each Section of this Examples Manual as follows:

KYPipe Docs

Examples Manual

1 Demonstration Examples

KYPipe Demonstrations

Surge Demonstrations

2 Class Exercises 1

3 Class Exercises 2

4 Training Exercises

5 Case Studies

6 Campus Facilities

7 Surge Demos

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Section 1 – Demonstration Examples

KYPipe Demonstrations and Example Data

Demo1 – Municipal Water Distribution System

A simple pipe system representing the main pipes of a small municipal distribution system is shown in Figure 1-1. This system is used to demonstrate the use of KYPipe for regular and extended period simulations and Surge for surge analysis. A number of modeling features are demonstrated with the data files provided in the Examples folder (“Examples” button in the File Open menu). In this manual the data along with additional details are provided so the user can lay out and set up these examples. A number of additional exercises are presented to illustrate modeling elements and features.

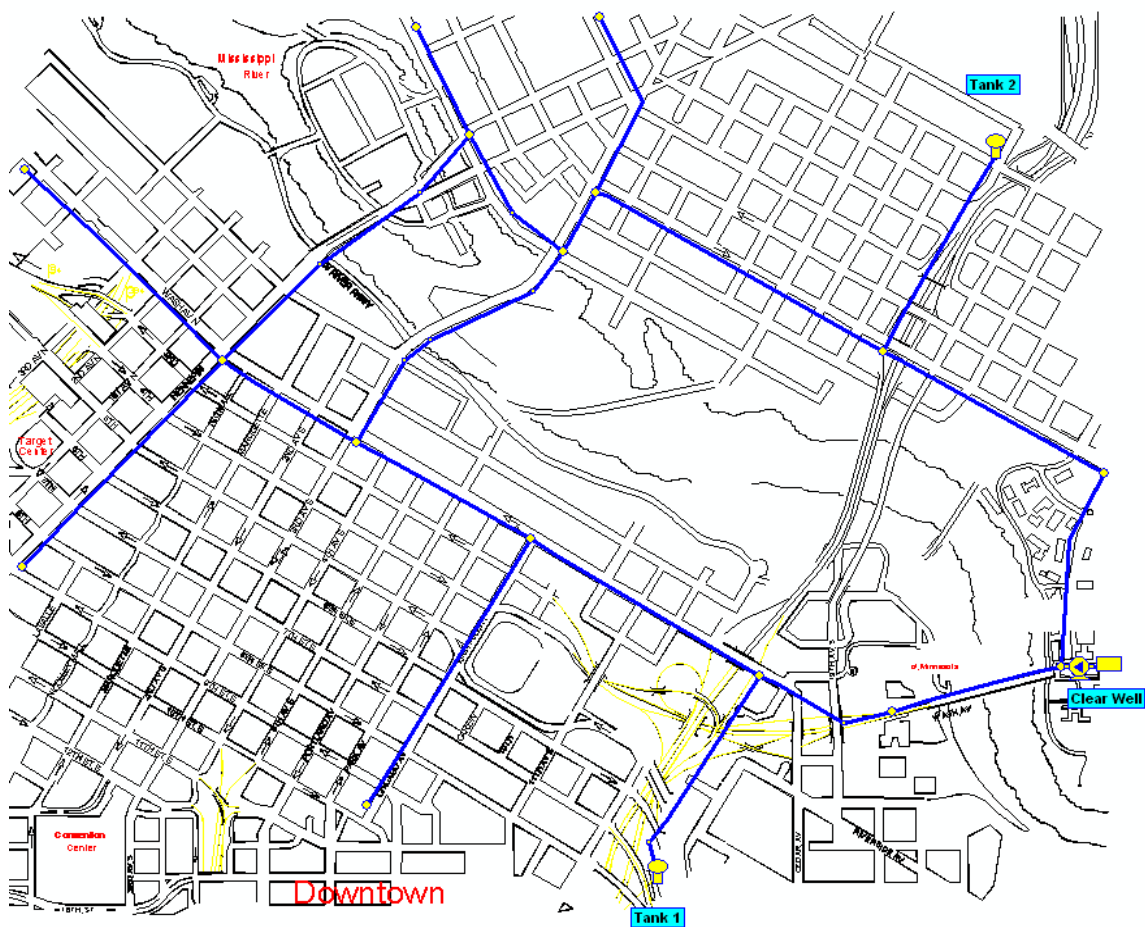


Figure 1-1 Pipe System – Demo1

1-1 Demo1 –Description of System

The system is supplied by a pump which has the following head/flow/efficiency data:

Head	Flow	Eff%
220	0	68
200	600	77
160	1200	70

The system has 2 overhead 35 foot diameter storage tanks with the following characteristics:

Tank 1: Max. elevation = 755 ft., Min elevation = 735 ft. Initial level = 750 ft.

Tank 2: Max. elevation = 755 ft., Min elevation = 730 ft. Initial level = 749 ft.

The pipes are 6, 8, and 10-inch ductile iron as shown below and the Hazen Williams Roughness coefficients are all 130. The pump suction and discharge lines are 12 inch ductile iron.

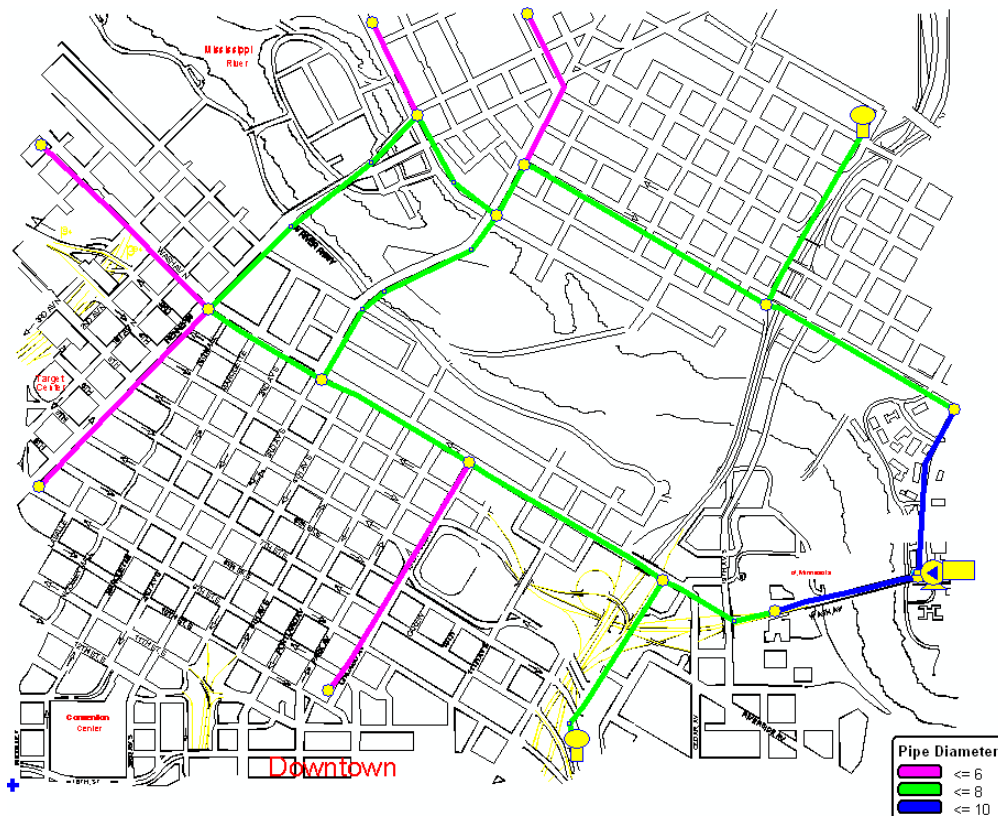


Figure 1-2 Pipe System Diameters - Demo1

The node elevations and demands (in gpm) are shown in the figures below.

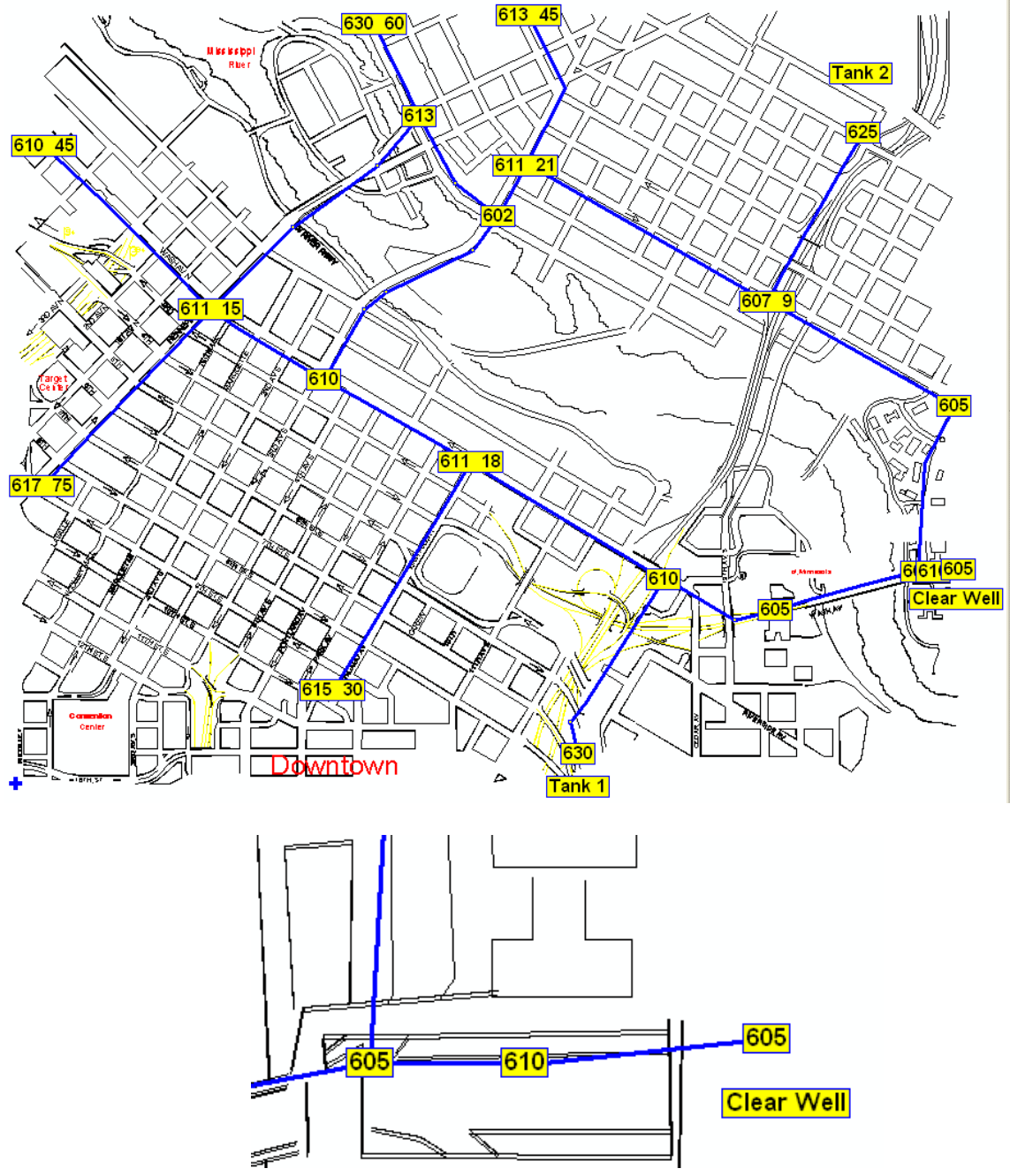


Figure 1-3 Pipe System Elevations and Demands - Demol

1-2 Demo1 – Developing a Model

Step 1 – Background Map - Ideally you will have a scaled background map which can be imported into Pipe2018 and used to lay out the pipes and automatically scale the pipe lengths. If available this map should be imported to use as the background for the pipe system. For this example the background map shown in Figures 1-1 to 1-3 is a .dwg file which is a scaled vector drawing file. This map is called City.dwg and may be found by clicking the Add Demo Map button in the Backgrounds menu shown below. The map is imported as a background map as shown in Figure 1-4a and 1-4b.

KYnetic Background menu icon: 

Classic tabs:

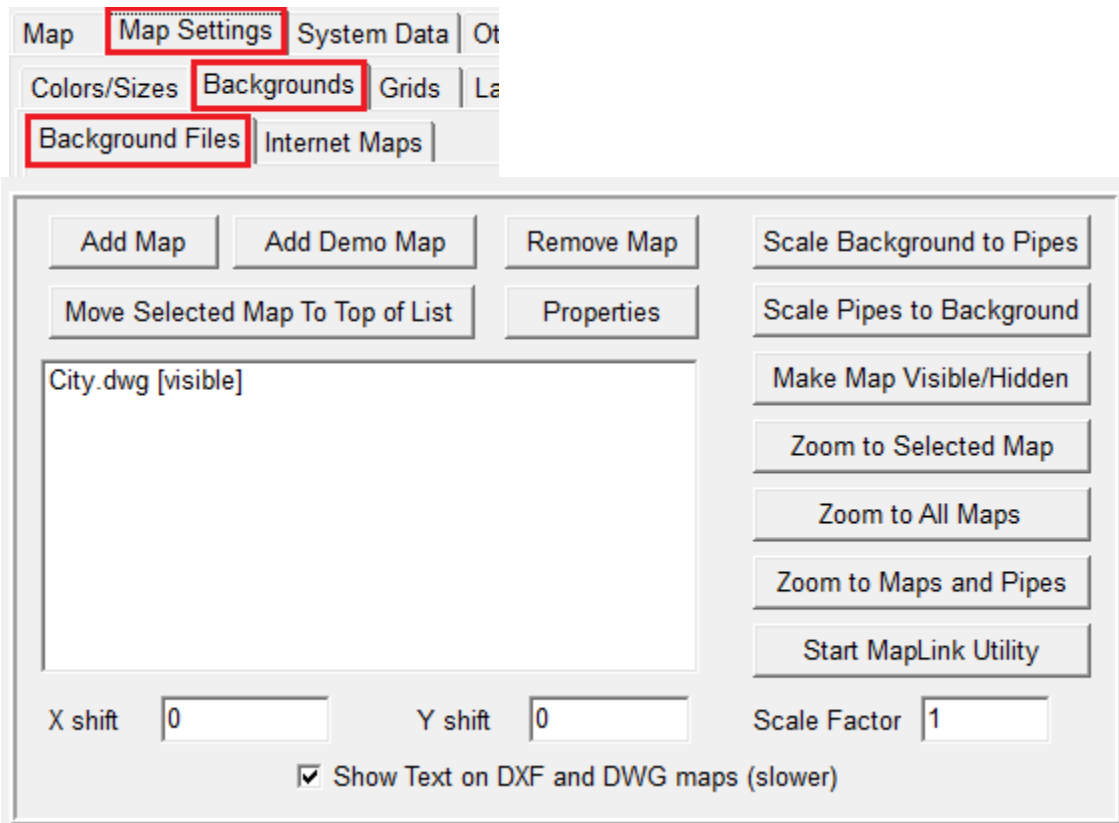


Figure 1-4a Adding the Background Map - Demo1

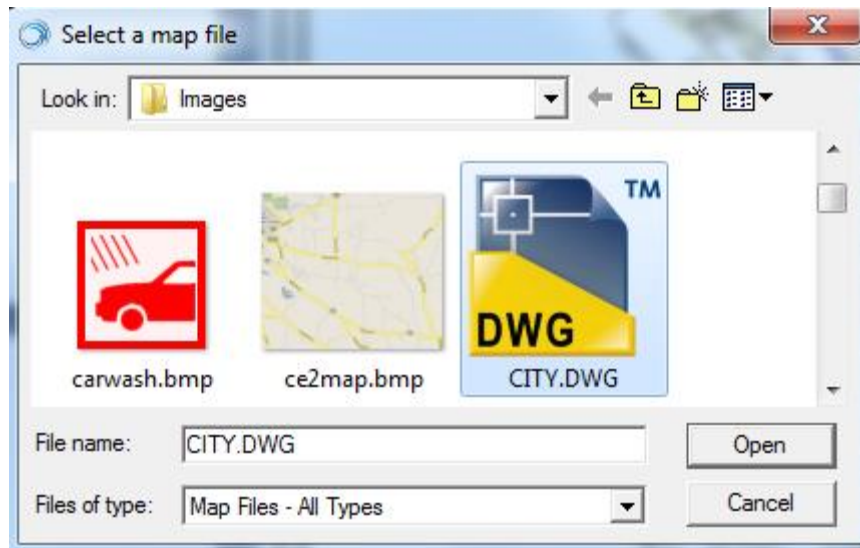


Figure 1-4b Adding the Background Map - Demo1

Step 2 – System Layout - Using the mouse and the background map as a guide the pipe system layout can be developed very quickly. Once the pipe layout is complete the two tanks, supply reservoir and pump nodes can be created by selecting the locations and using the Node Type dropdown list to designate the node type. At this point the pipe system will appear as shown below in Figure 1-5

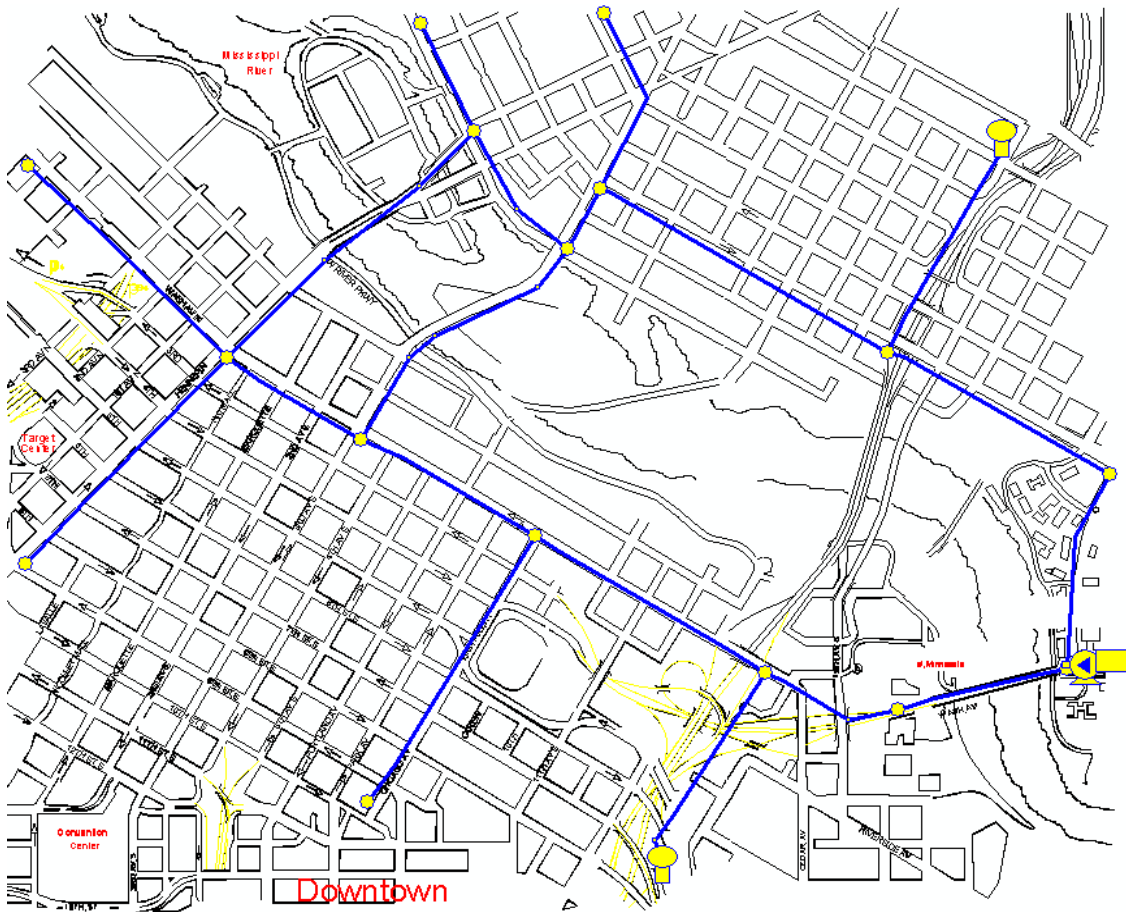



Figure 1-5 Pipe System Layout – Demo1

Step 3 – Provide Pipe Data - The recommended means to provide pipe data is to first develop the Pipe Type Table. This is accessed through the KYnetic Components menu icon  or the Classic tabs **Setup/Defaults | Pipe Type**. The following table is appropriate for this example. The Estimated 10 Year Roughness is utilized with the aging feature and is optional.

	Material	Rating	Nominal Diameter	Actual Diameter	Unit Cost	Reference Roughness	Estimated 10yr Roughness
1	di	150	6			130	119
2	di	150	8			130	120
3	di	150	10			130	121
4	di	150	12			130	122

Figure 1-6 Pipe Type Table – Demo1

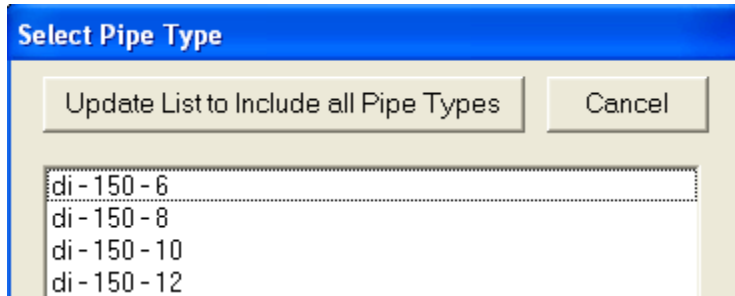
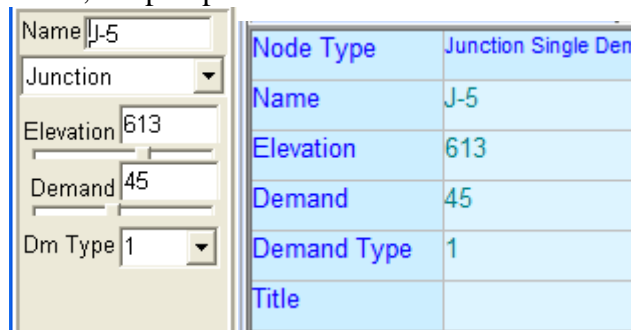


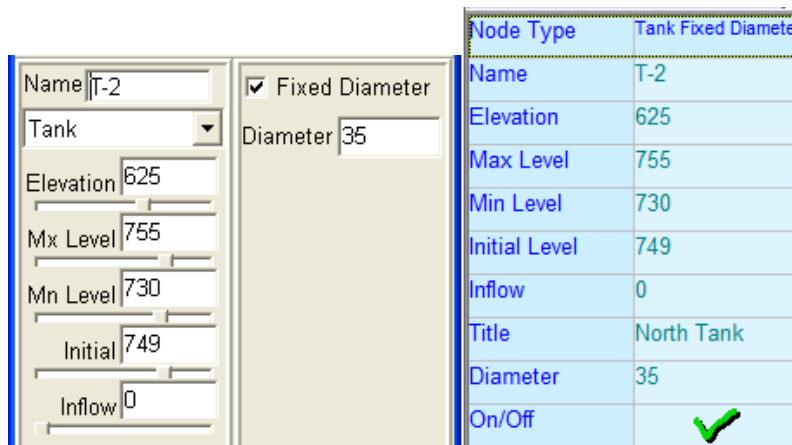
Figure 1-7 Pipe Type Table – Demo1

Figure 1-7 illustrates the Pipe Type data entry. When the pipe is selected in the map and Pipe Type is clicked the menu shown above appears. A click on the second entry (di-150-8) will result in all the data items except Length being entered into the pipe data box. The length has been scaled using the background map so only the entry for Pipe Type is needed to provide the required pipe data. Additional data for Fittings or other features may be entered but this is optional. The Pipe Type is entered for each pipe to complete the data requirements for pipes.

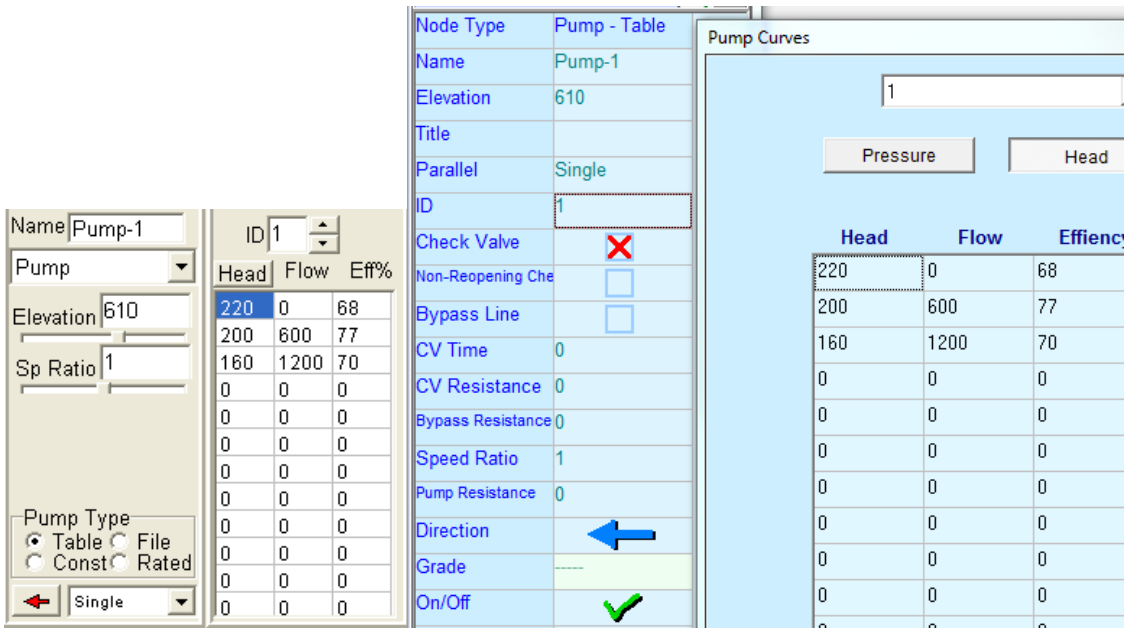
Step 4 – Provide Node Data - Data is then entered for each node in the system. The data requirements vary depending on the Node Type. Node data entry is illustrated below for the top center junction, the pump and Tank 2.



Junction Node: Classic – KYnetic



Tank (Fixed Diameter): Classic - KYnetic

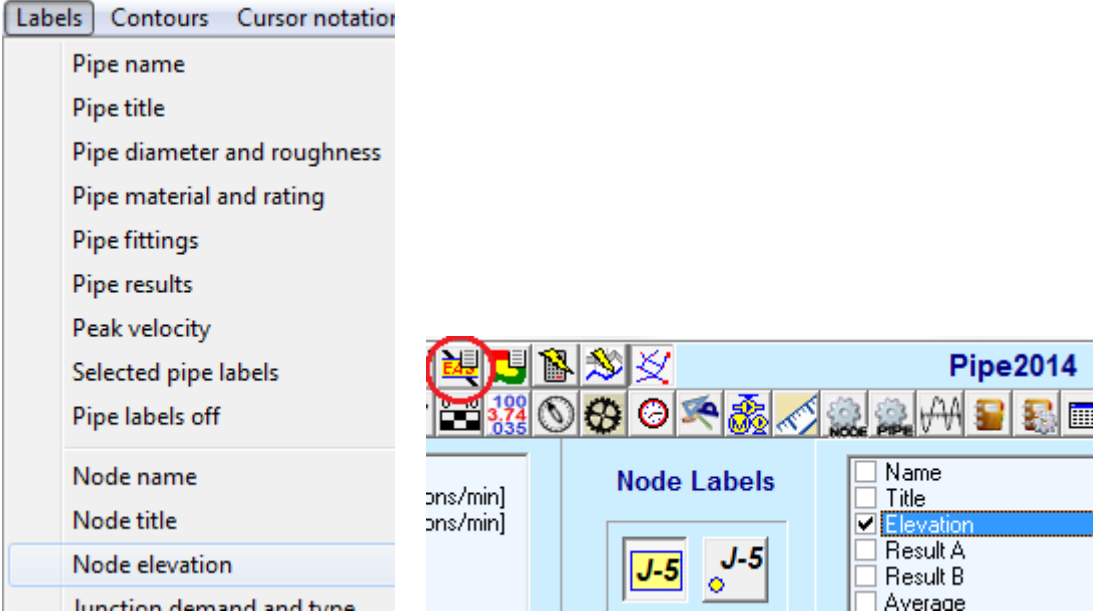


Pump (Table): Classic – KYnetic

Figures 1-8 Node Data – Demo1

1-3 Demo1 – Regular Simulations and Changes (Demo Model.P2K)

Step 1 – Check the Data and Run the Analysis - Once data entry is complete various data checks should be performed. A graphical data check is very useful and is performed by turning on labels such as Node Elevation and Pipe Diameter and Roughness as shown in Figure 1-9.



Labels menu – Node Elevations: Classic - KYnetic

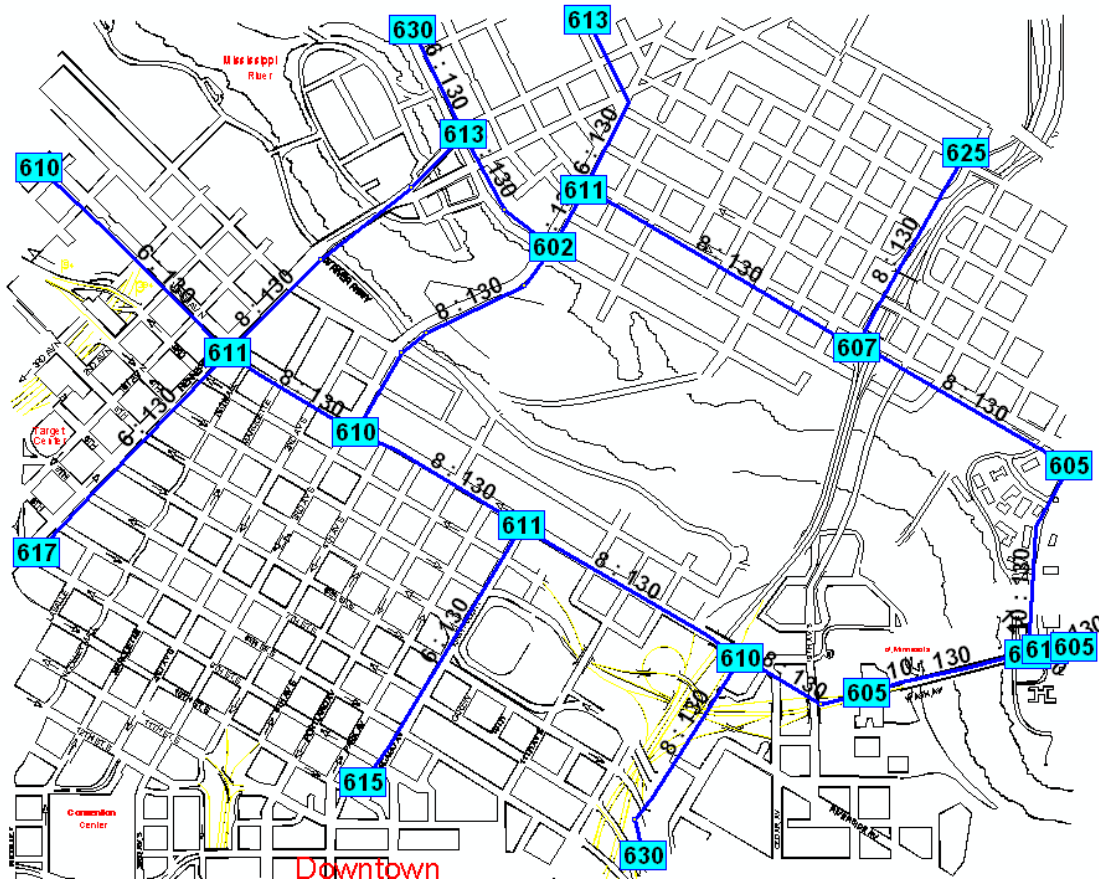


Figure 1-9 Graphically Checking Data – Demo1-1

Analyze Labels Contours

Error Check

Connectivity Check

Find/Purge Parallel Pipes

OCS Screen (Analysis)

Analysis

Summary/Supply Plot

Inventory/Cost

Power Cost

Profile

Skeletonize

Calibration Wizard

Undo Calibration

Information

No Errors

OK

Classic

Analyze Labels Contours

Error Check

Connectivity Check

Find/Purge Parallel Pipes

OCS Screen (Analysis)

Analysis

Summary/Supply Plot

Inventory/Cost

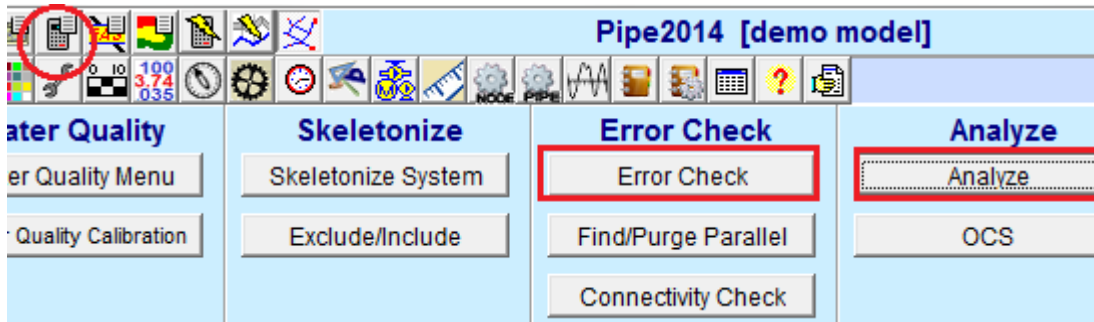
Power Cost

Profile

Skeletonize

Calibration Wizard

Undo Calibration



KYnetic

Figure 1-10 Error Check and Analysis Data – Demo1-1

Once the data is reviewed an Error Check should be performed as shown in Figure 1-10. Then an Analysis can be carried out as shown also in Figure 1-10. The analysis will be for the Baseline Conditions described by the input data. The results for pressures at nodes are shown in Figure 1-11.

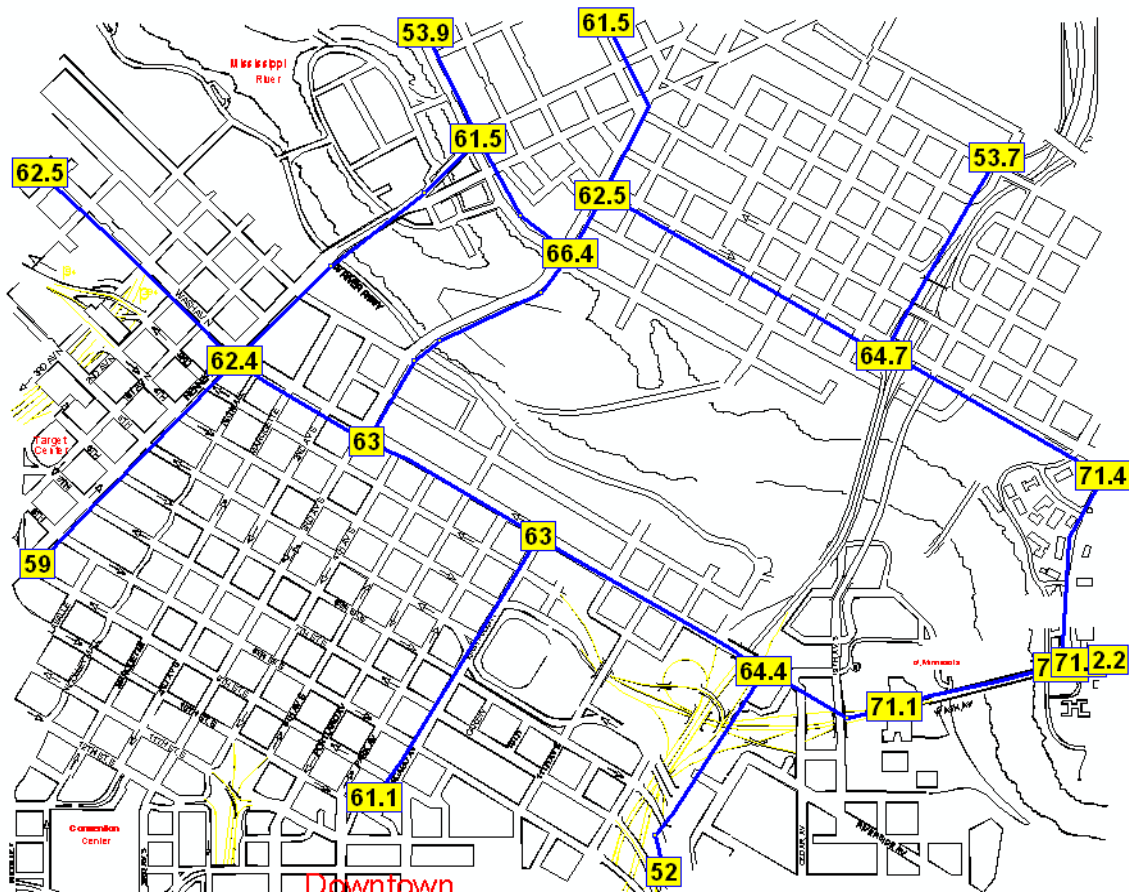


Figure 1-11 Node Pressures for Baseline Data – Demo1-1

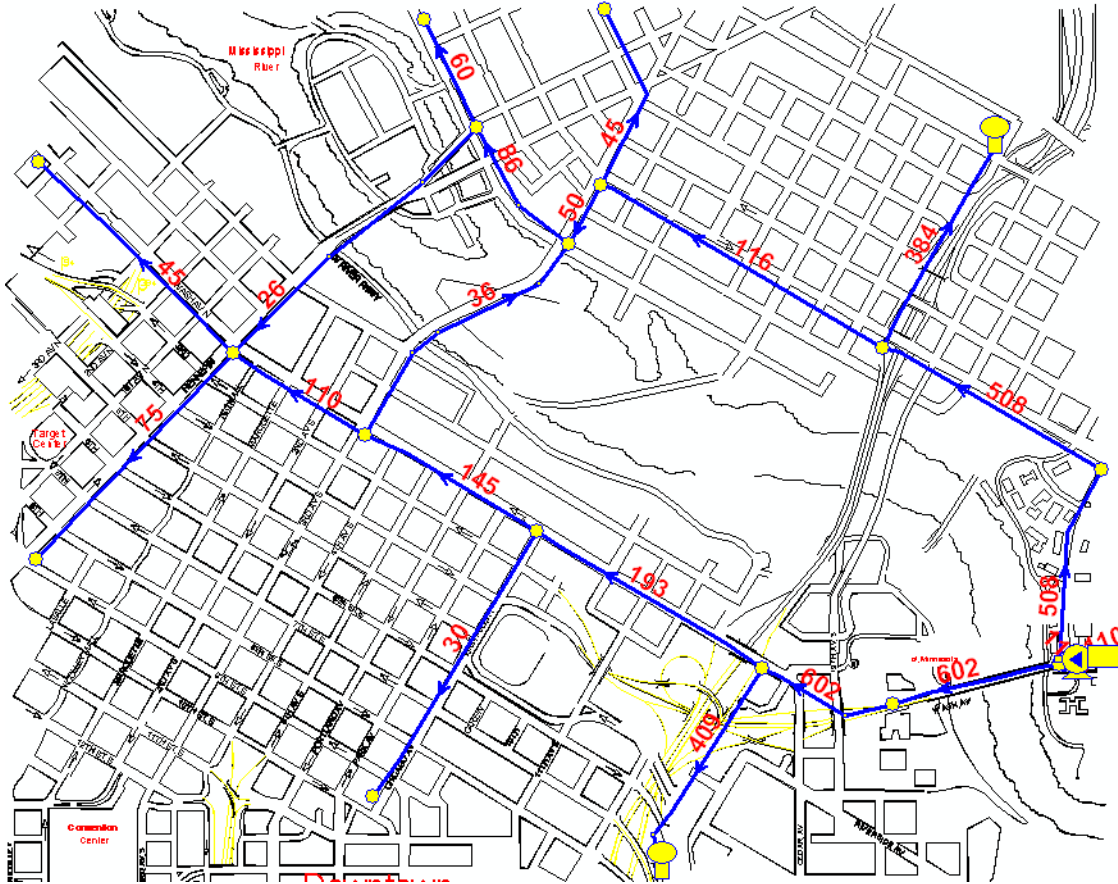


Figure 1-12 Pipe Flows (gpm) for Baseline Data – Demo1-1

Step 2 – Add Change Data and Run Additional Simulations - It is desired to set up the following three scenarios:


Case 0 - The pump is running with normal (Baseline) demands

Case 1 - The pump is off and the tanks supply the system

Case 2 - The pump is off and a fire demand of 650 gpm is placed at Junction J-13

The first simulation (Case 0) is always the Baseline Data and is the analysis illustrated in Section 3-1 Step 1. The additional cases may be run by modifying the Baseline data and re-running the analysis. However, Pipe2018 has the capability to run multiple simulations by specifying Changes to various Pipe and Node parameters, allowing the Baseline Data to remain the unchanged. One advantage of this approach is that the results for the various cases are easily compared in Tables and Graphs.

The Change Data screens used to set up these 2 additional simulations are shown in Figure 1-12. These are accessed by clicking on the node in the map screen and selecting

the  icon at the bottom of the Node Info window (KYnetic) or the ‘Chng’ (Change)

button at the top of the node information window (Classic). To set up an additional case just select the node(s) and/or pipe(s) and enter the desired case number, parameter type (click center column and select from list) and the new parameter value.

The screenshot shows the 'Node Changes' dialog box with a table titled 'Changes for Pump-1'. The table has three columns: 'Case', 'Change', and 'Value'. The first row contains the values '1', 'Closed', and 'Close'.

Case	Change	Value
1	Closed	Close

Case 1: Classic - KYnetic

The screenshot shows the 'Node Changes' dialog box with a table titled 'Changes for J-13'. The table has three columns: 'Case', 'Change', and 'Value'. The first row contains the values '2', 'Demand', and '650'.

Case	Change	Value
2	Demand	650

Case 2: Classic - KYnetic

Figure 1-13 Change Data for Cases 1 and 2 – Demo1-1

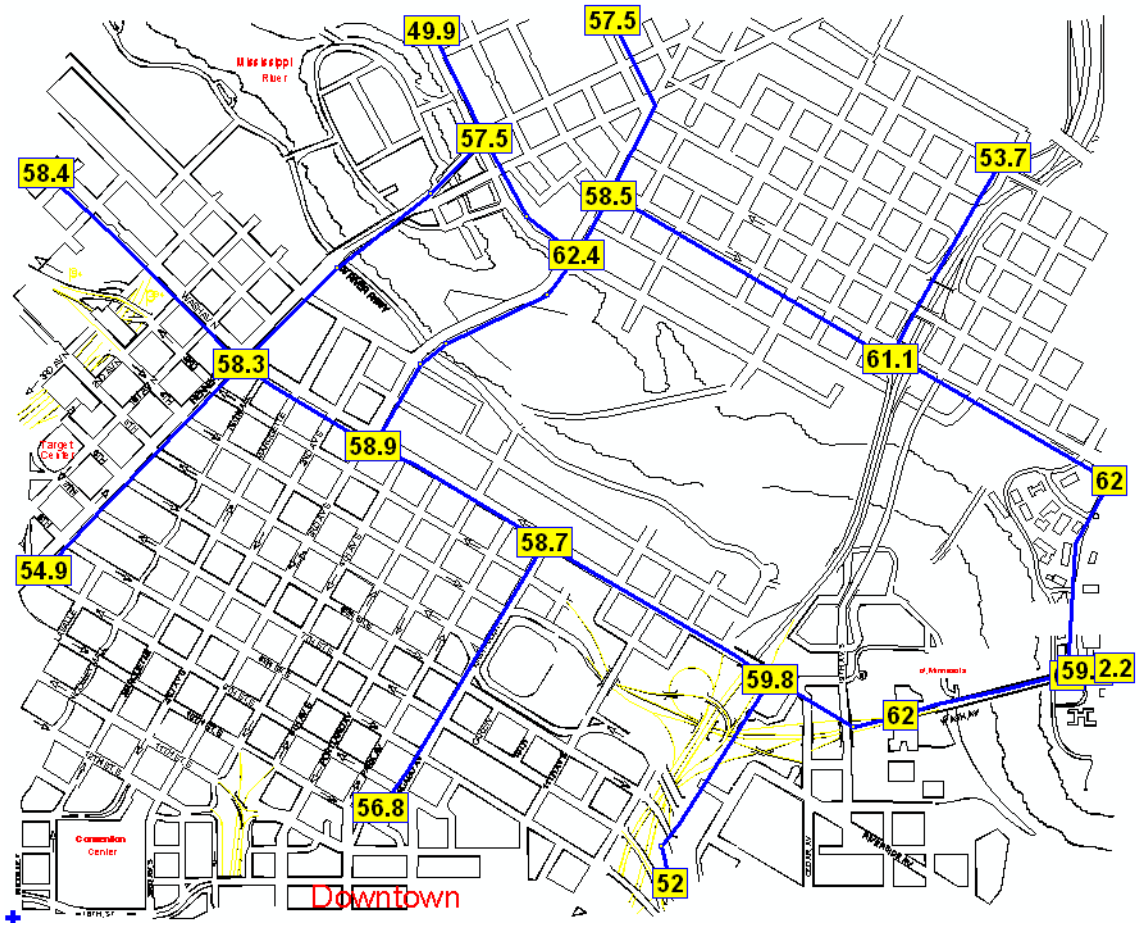


Figure 1-14 Node Pressures for Case 1, Pump off – Demo1-1

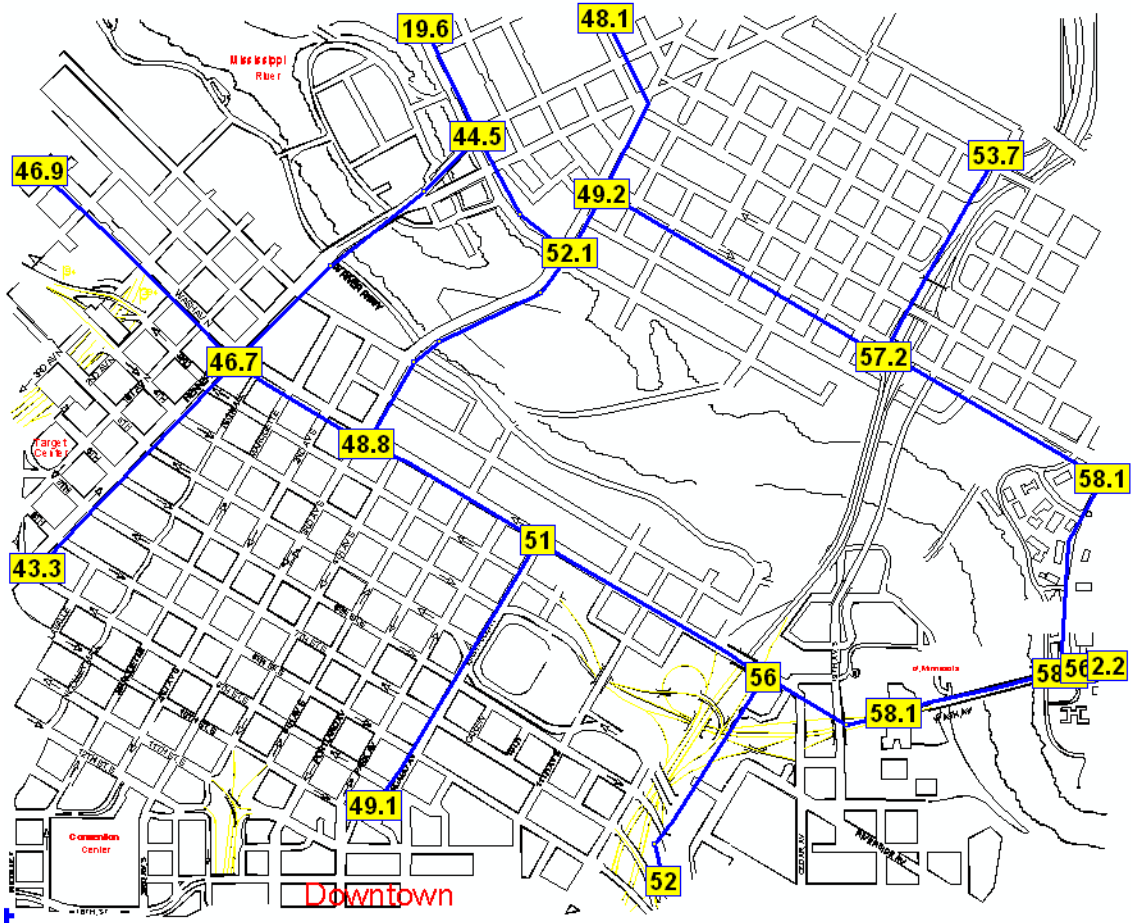
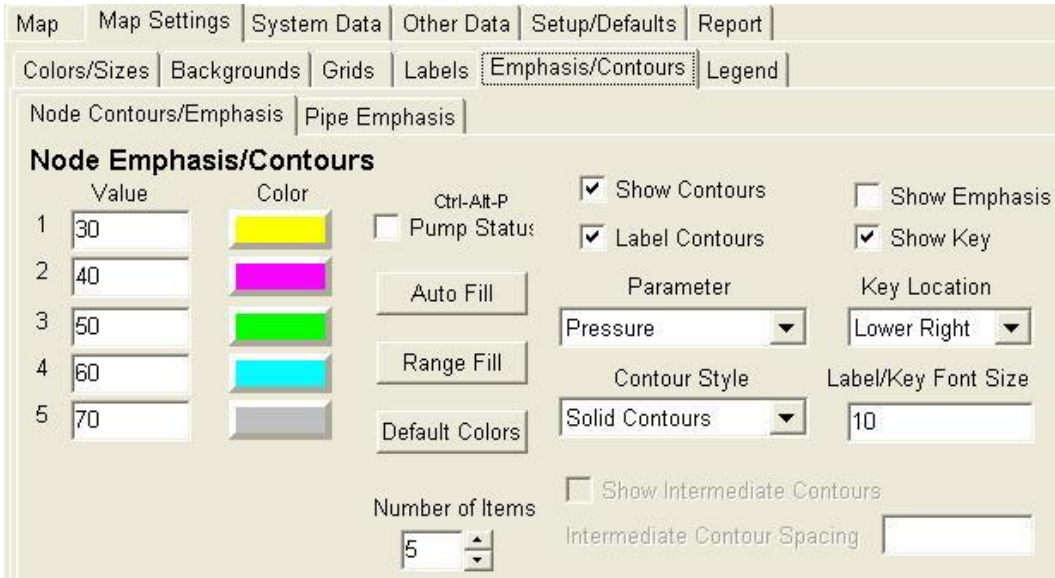
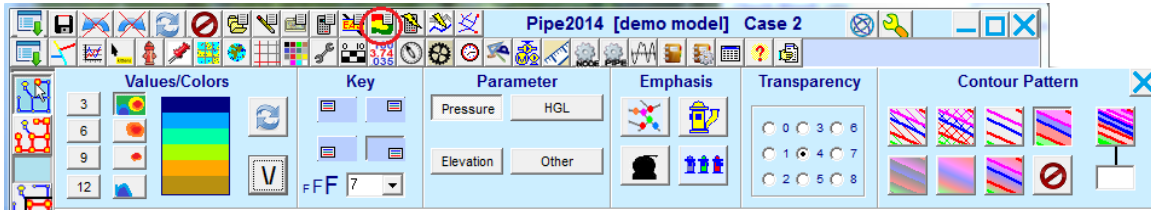


Figure 1-15a Node Pressures for Case 2, Pump Off, Demand 650 gpm – Demo1-1

Pressure contours are an effective alternate way to present results. Figure 1-15b shows the setup screens and the resulting pressure contour plot for Case 2.



Classic Contours menu



KYnetic Contours menu

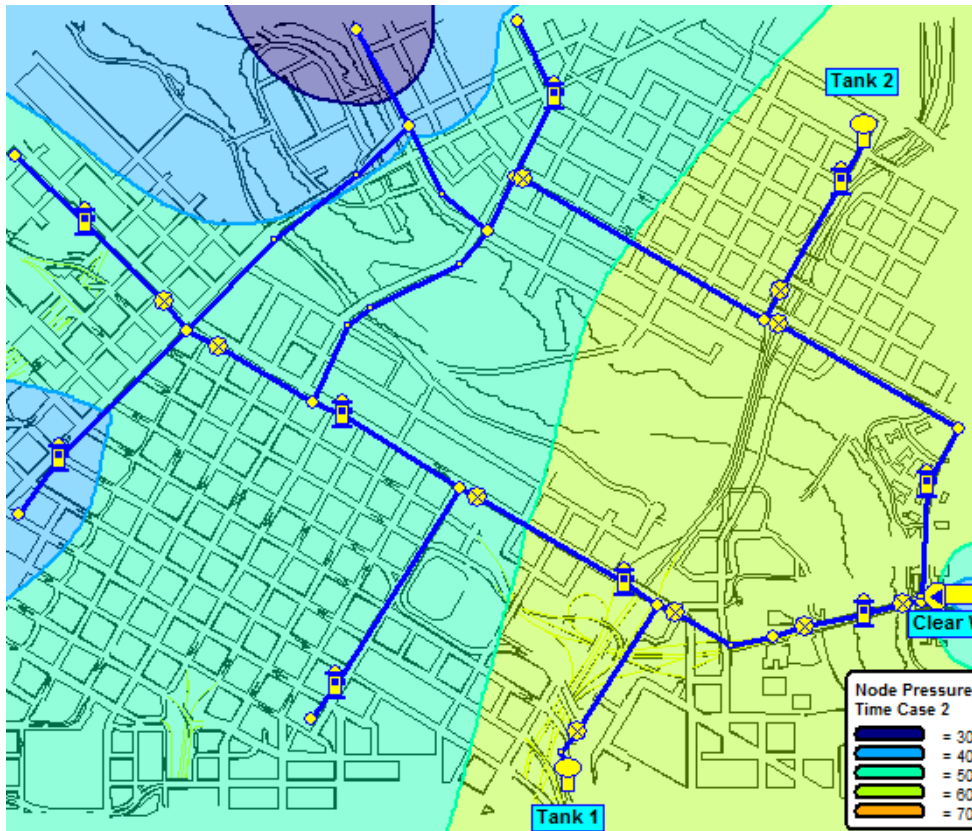


Figure 1-15b Node Pressures Contours for Case 2 – Demo1-1

1-4 Demo1-2 – Additional Node Types (Demo Other Nodes.p2k)

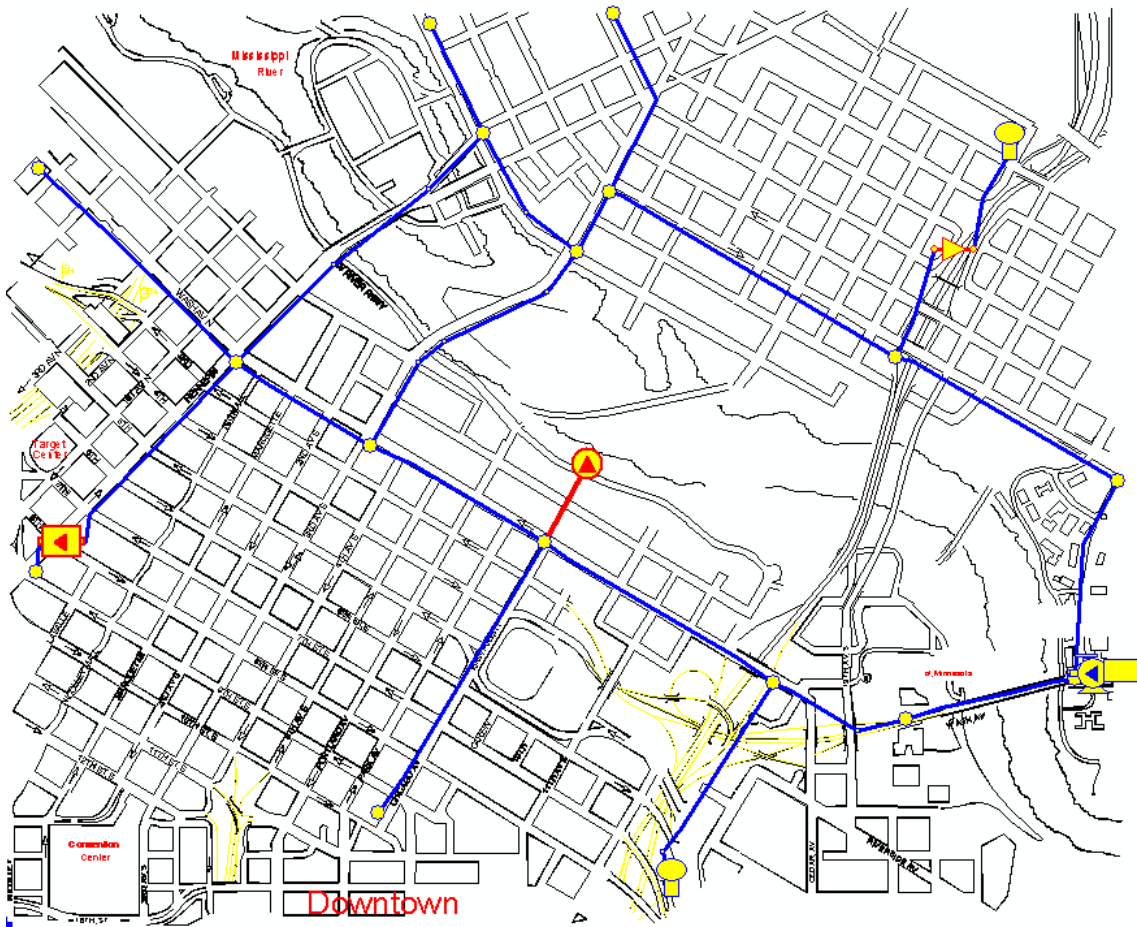



Figure 1-16 Additional Node Types – Demo1-2


A number of additional Node Types are illustrated in this example. These include:

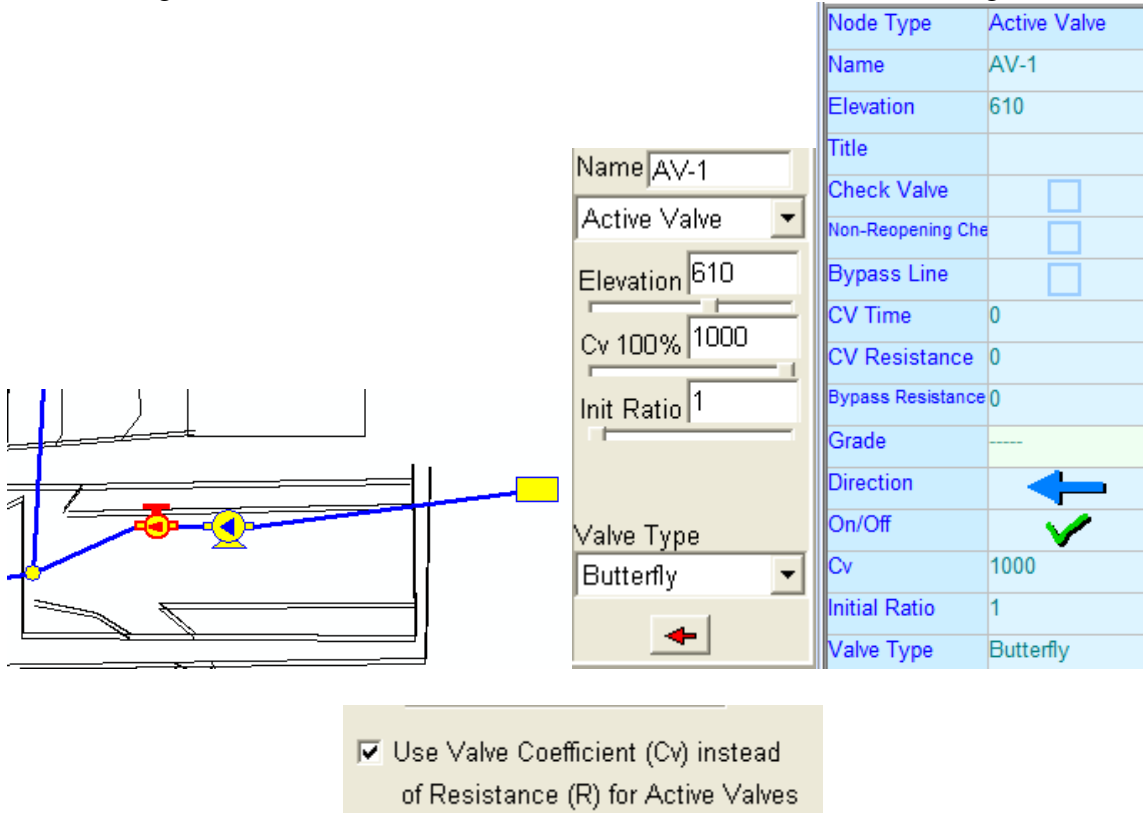
- a) Active Valve
- b) Regulator
- c) Loss Element
- d) Sprinkler



For items a, b, and c insert a node at the indicated location. To Insert click on pipe at the

intended location and select Insert icon  (bottom of Pipe Info window in KYnetic) or “Insrt” button (top left of Pipe Information window in Classic). Then select the node type from the drop-down list.

The Active Valve is a pump control valve located just downstream from the pump. It is a 10 inch Butterfly valve with a $C_v = 1000$ when fully opened. Note that an Active Valve

can be characterized by the wide open Flow Coefficient (Cv100%) or the wide open Resistance (R100%). A check box in the Preferences menu  (KYnetic) or System Data | Preferences (Classic) is available to switch from one description to the other (as shown in Figure 1-17). The data boxes for this Active Valve are shown in Figure 1-17.



Node Type	Active Valve
Name	AV-1
Elevation	610
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0
Bypass Resistance	0
Grade	-----
Direction	
On/Off	
Cv	1000
Initial Ratio	1
Valve Type	Butterfly

Use Valve Coefficient (Cv) instead of Resistance (R) for Active Valves

Figure 1-17 Active Valve Data – Demo1-2: Classic - KYnetic

A Flow Control Valve is located in the pipe leading to Tank 2 to limit the flow to 300 gpm. The setup for this element is shown in Figure 1-18. In addition a Backflow Preventor located in the pipe leading to J-2 on the lower left side in the pipe system. This device has head loss vs. flow data and uses a curve based on this data to determine the loss through the element. The data for these elements is shown in Figure 1-18

The screenshot shows the properties for a Flow Control Regulator (RV-1). The Name is RV-1, Regulator is set to a dropdown, Elevation is 615, Setting is 300, and Regulator Type is FCV-1. A red arrow icon is at the bottom. To the right is a data table:

Node Type	Regulator
Name	RV-1
Elevation	615
Title	
Direction	
Setting	300
Type	FCV-1
Cv	0

Flow Control Regulator: Classic – KYnetic

The screenshot shows the properties for a Loss Element (L-1). The Name is L-1, Loss Element is set to a dropdown, and Elevation is 617. A table shows Head (20, 25, 35, 0) and Flow (50, 70, 100, 0) values. To the right is a data table:

Node Type	Loss Element
Name	L-1
Elevation	617
Title	
Grade	---
ID	2

Loss Element: Classic – KYnetic

Figure 1-18 Regulator and Loss Element Data – Demo1-2

The screenshot shows the properties for a Sprinkler (S-1). The Name is S-1, Sprinkler/Leak is set to a dropdown, Elevation is 580, Constant is 18.5, Length is 4, Diameter is 2, Elev Chg is 4, and Elbows is 0. A red line with a yellow triangle and a green checkmark are shown. To the right is a data table:

Node Type	Sprinkler/Leak
Name	S-1
Elevation	580
Title	
On/Off	
Constant	18.5
Length	4
Diameter	2
Elevation Change	4
Elbows	0

Sprinkler Data: Classic - KYnetic


Name	P-25
Pipe Type	
Diam	6
Mtrl	di
Rtng	150
Length	900 <input checked="" type="checkbox"/> F
Rough	130 <input checked="" type="checkbox"/> F
Fittings	<input type="checkbox"/> Closed

Name	P-25
Pipe Type	di - 150 - 6
Length	900
Roughness	130
Fittings	
First Node	J-8
Last Node	S-1
Residential Meters	0
Install Year	2001
Title	
Closed	<input type="checkbox"/>

Additional Pipe Data: Classic - KYnetic

Figure 1-19 Additional Pipe and Sprinkler Data – Demo1-2

For item d select the existing node and move the mouse to the location of the sprinkler and RC. Then select the new node and change it to a sprinkler. A 900 foot long 4 inch line leading to a 1 inch sprinkler (orifice) was added to model a fountain. At the fountain a 4 foot long 2 inch pipe rises 4 feet to the sprinkler orifice. The data for the additional pipe and sprinkler are shown in Figure 1-19. Data for the pipe connecting a sprinkler is included with the sprinkler data. The Sprinkler Constant can be obtained using the Sprinkler/Blowoff Constant Tool as shown below.

KYnetic Tools menu icon: 

- Air Slam Pressure Surge
- Air Valve Orifice Size
- Bladder Precharge
- Calculator
- Force Calculations
- Gas Properties
- Generate Intermediate Pump File
- Hose and Nozzle Constants
- Inertia/Specific Speed
- Modulating (Regulating) Valve
- Power (HP or KW) Calculations
- Profile Import
- Pump File Characteristics
- Residual Pressure Adjustment
- Resistance Calculations
- Select Pump File
- Spike Track
- Sprinkler/Blowoff Constant**
- Units Convertor
- Valve Stroking
- Wave Speed

Pipe2000 - Sprinkler/Blowoff C...

Unit: English

Compute Based on: Orifice diameter

Diameter of Orifice: 1 in

Diameter of Pipe: 2 in

Discharge Coefficient: 0.62

Specific Gravity: 1

Sprinkler Constant K_s : 18.476

$K_s = Q / (dP^{0.5})$, where K_s is sprinkler constant, Q is flowrate in gpm (or l/s) and dP is pressure drop in psi (or kPa)

Figure 1-20 Sprinkler/Blowoff Constant Tool – Demo1-2

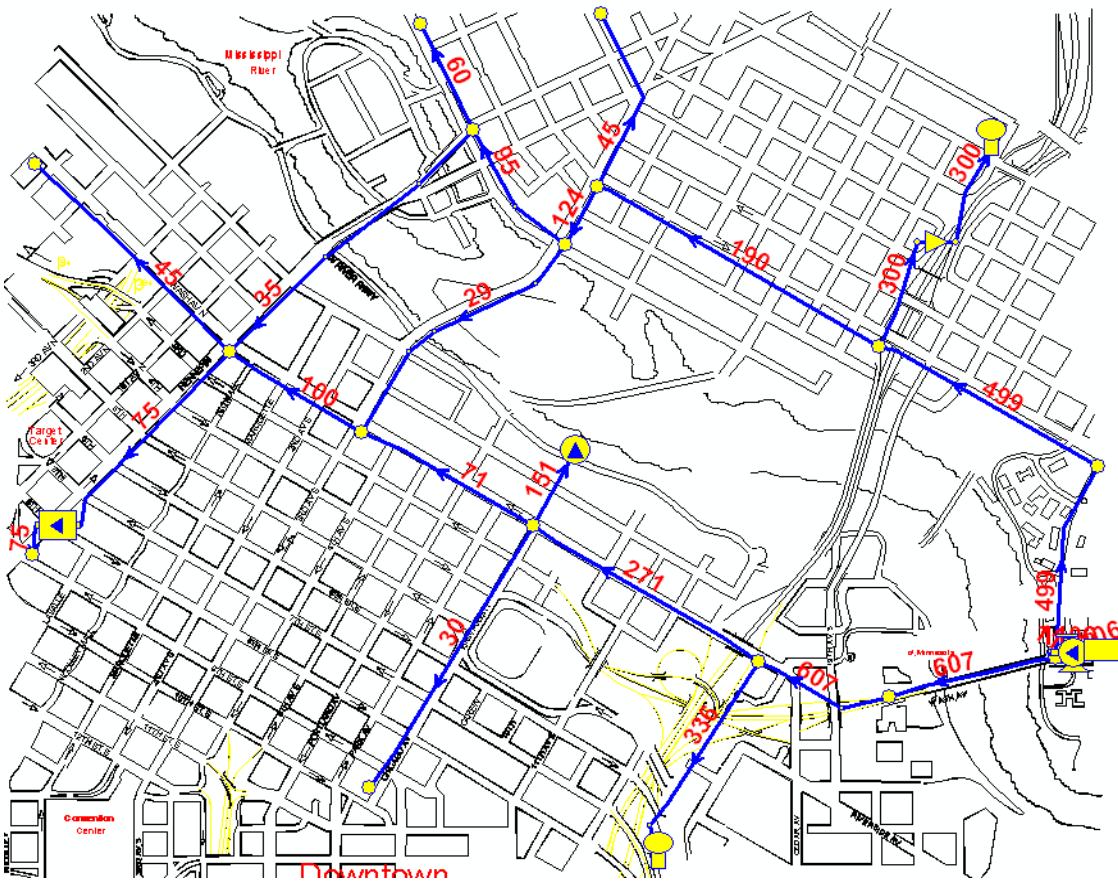
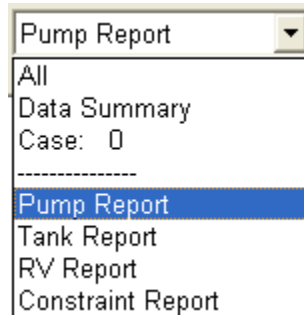


Figure 1-21a Flowrates (gpm) – Demo1-2

Figure 1-21a and 1-21b show the pressures and flows obtained by the hydraulic analysis which includes the additional elements. The Tabulated Report contains additional sections summarizing results for various elements. The dropdown list illustrated below

may be accessed when  (KYnetic) or **Report** tab (Classic) is selected. Figure 1-22 shows the report generated for Pumps and Regulators.



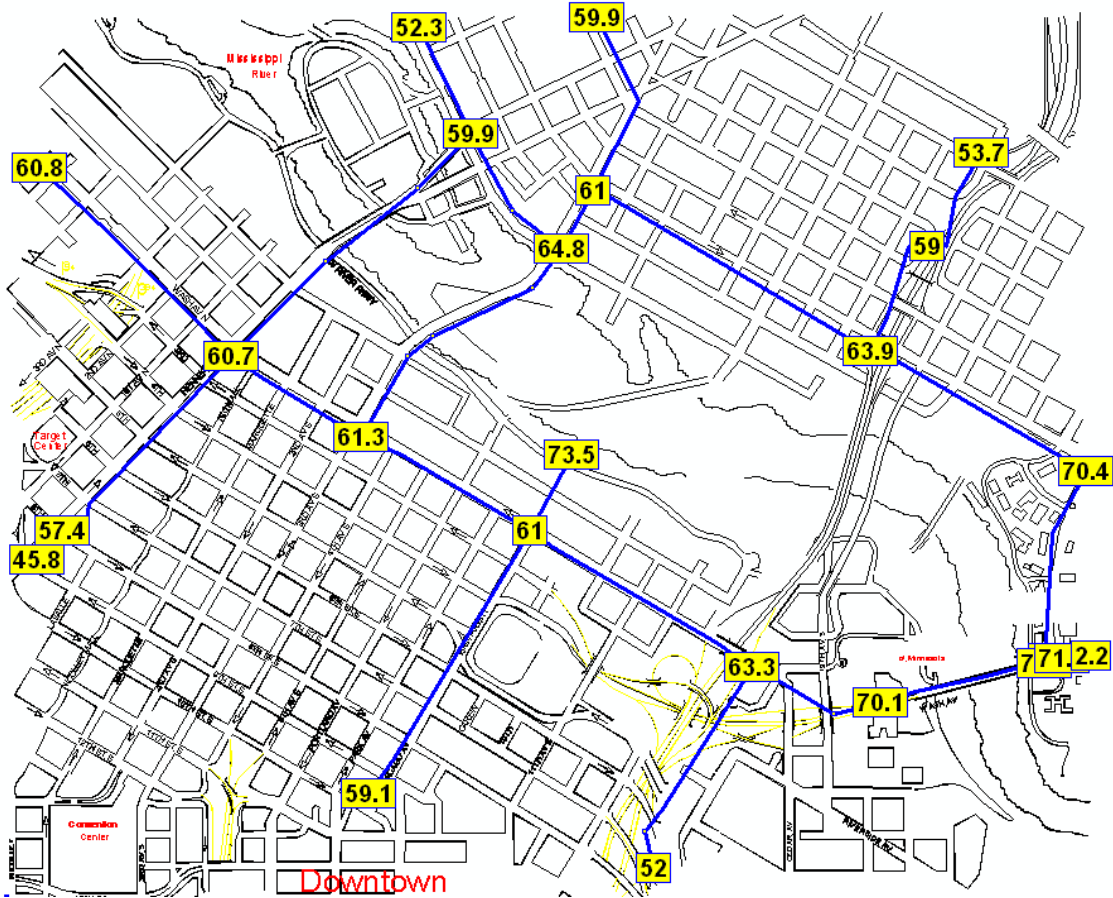


Figure 1-21b Pressures (psi) Demo1-2

PUMP/LOSS ELEMENT RESULTS

NAME	FLOWRATE (gpm)	INLET HEAD (ft)	OUTLET HEAD (ft)	PUMP HEAD (ft)	EFFIC- ENCY (%)	USEFUL POWER (Hp)	INCREMENTL COST (\$)	TOTAL COST (\$)	#PUMPS PARALLEL	#PUMPS SERIES	NPSH Avail. (ft)
L-1	75.00	132.49	105.96	-26.5	----	----	---	----	**	**	165.7
Pump-1	1105.50	-2.04	165.28	167.3	----	----	---	----	**	**	31.0

REGULATING VALVE REPORT

VALVE	VALVE	VALVE (psi or gpm)	VALVE	UPSTREAM (psi)	DOWNSTREAM (psi)	THROUGH (gpm)
RV-1	FCV-1	300.00	ACTIVATED	59.38	59.01	300.00

Figure 1-22 Pump and Regulator Reports - Demo1-2

1-5 Demo1-3 – Fire Hydrants (Demo Hydrant Analysis.P2K)

Locations and reference names are shown below (Figure 1-23) for 9 fire hydrants. Fire flow test data for the hydrants is shown in Figure 1-24. To Insert these hydrants, click on



pipe at the appropriate location and select Insert icon (bottom of Pipe Info window in KYnetic) or “Insrt” button (top left of Pipe Information window in Classic). Then select Hydrant from the drop-down list.

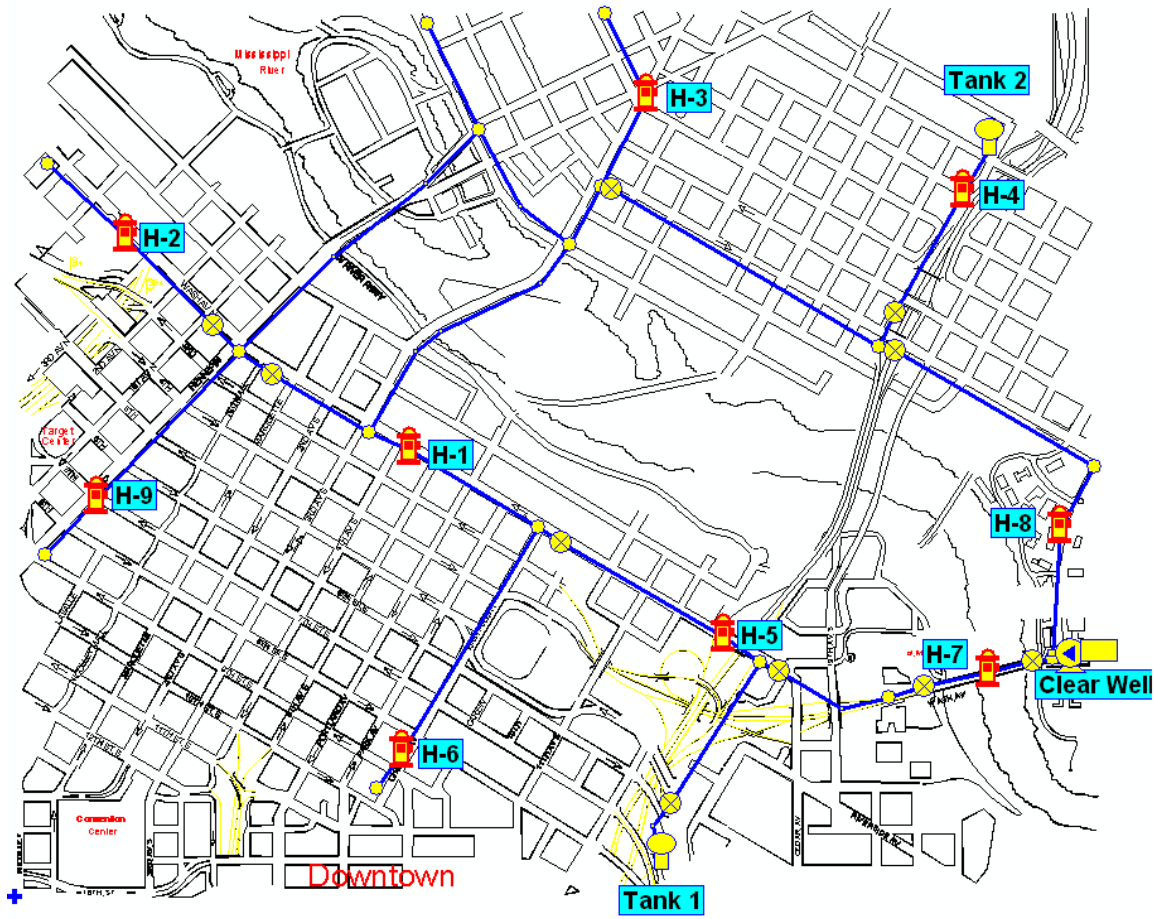


Figure 1-23 Fire Hydrant Locations Demo1-3

Name	Elv.	Static Pressure	Residual Pressure	Residual Flow
H-1	611	66	47	800
H-2	612	58	44	370
H-3	610	59	34	660
H-4	620	54	46	1400
H-5	610	65	39	1550
H-6	615	63	44	370
H-7	605	71	60	1700
H-8	605	70	58	1330
H-9	615	58	32	407

Figure 1-24 Fire Hydrant Test Data - Demo1-3

Name	H-1
Hydrant	
Elevation	611
St Prs	66
RsdI Prs	47
RsdI Flow	800
Graph	
Measured Data	

Node Type	Hydrant
Name	H- 1
Elevation	611
Title	
Static Pressure	66
Residual Pressure	47
Residual Flow	800
Calculated St Press	62.7
Calculated Fireflow	1718.099

Hydrant Data: Classic – KYnetic

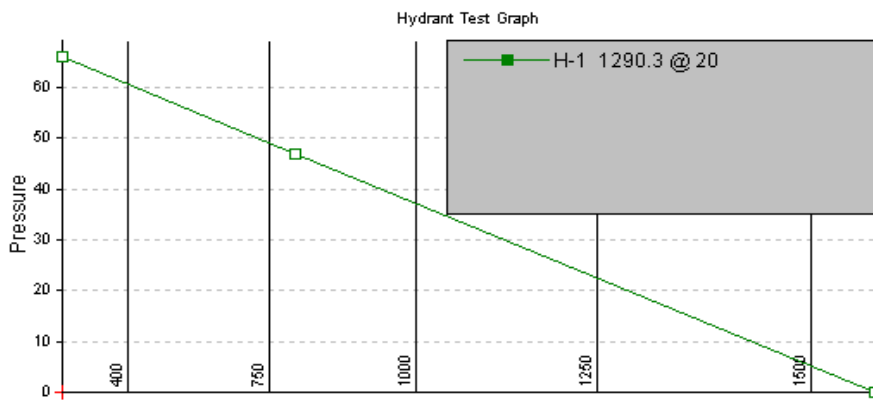
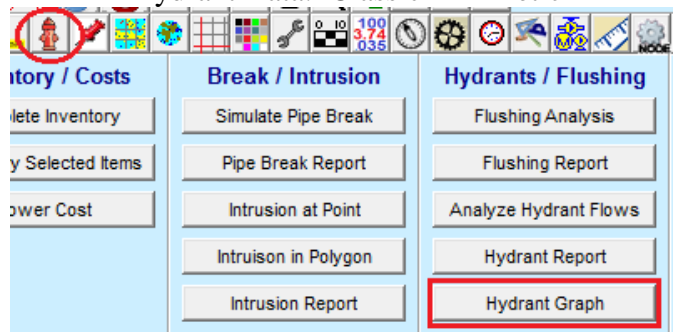


Figure 1-25 Fire Hydrant (Test) Data and Flow Plot - Demo1-3

Once a hydrant is added the hydrant can be selected and the elevation and fire flow data shown in Figure 1-26 can be entered as shown above (for reference and graphing only, not used for calculation). The **Graph** button or the KYnetic menu shown above allows you to generate Fire Flow Test Data plots such as the one shown in Figure 1-25. This plot using a $Q^{1.85}$ factor for the X axis is used for predicting the available fire flow from the test data (this follows AWWA and NFPA guidelines). Hydrants also allow you to use a model to calculate available fire flows. The Analysis Setup screen for Fire Flow calculations is shown below in Figure 1-26. Pipe2018 provides a variety of fire flow and hydrant flushing calculations although the most common is the Available Fire Flow at a Specified pressure (usually 20 psi) which is illustrated below.

Analysis Setup

Analysis Year: Use Current Year

Analyze
Cancel

Analysis Type

KYPipe
 Water Quality (EPANET)
 Hydraulic Calibration
 Rural Analysis
 Fireflow and Hydrant Analysis
 System Head Curves

Flushing Planner
 Locate Remote Sprinkler Area
 Water Quality Calibration
 Temperature Dependent Liquid
 Required Capacity (Sprinklers)

Sort Numerically (slower) Report Shows All Flows As Positive Numbers
 Save System Before Analysis

Load set of results. Load all times Start End

Minimum Pressure for Fireflows

Static Pressure Limit (nodes with static pressure below this value will be ignored)

Fireflow Nodes
 Selected Hydrants
 All Hydrants
 Selected Junctions Nodes
 All Junction Nodes

Generate Flushing Report (Hydrants and Blowoffs)

Figure 1-26 Fire Flow Calculations Set Up Screen - Demo1-3

Fireflow/Hydrant Report:

Specified Minimum Pressure (psi or kPa): 20.0
 Minimum Static Pressure (psi or kPa) : 0.0
 Sp.Min Pres@FirePump Suctn (psi or kPa): 0.0

Flow-1: Flowrate to maintain the specified pressure at (hydrant) node
 Node-2: Node that has a lower pressure than specified value at Flow-1
 Flow-2: Flowrate to maintain the specified pressure at Node-2
 Flow-3: Flowrate to maintain the specified pressure at Fire Pump Suction

Hydrant Node	Elevation	Demand gpm	Static Pressure	Flow-1 gpm	Flow-2 gpm	Node-2	Flow-3 gpm	Flow Capacity	NFPA Color
H-9	615.0	0.0	60.1	557.3	547.6	J-2	713.5	547.6	ORANGE
H-2	612.0	0.0	61.7	654.9			835.9	654.9	ORANGE
H-7	605.0	0.0	72.2	3962.6			4804.8	3962.6	BLUE
H-1	611.0	0.0	62.7	1718.1	1644.1	J-13	2169.0	1644.1	BLUE
H-8	605.0	0.0	71.9	3570.6			4421.1	3570.6	BLUE
H-4	620.0	0.0	56.6	4336.6			5476.9	4336.6	BLUE
H-3	610.0	0.0	62.9	870.6	852.9	J-5	1084.1	852.9	ORANGE
H-5	610.0	0.0	64.3	2764.3			3583.0	2764.3	BLUE
H-6	615.0	0.0	61.1	562.4			714.3	562.4	ORANGE



Figure 1-27 Fire Hydrant Analysis and Report - Demo1-3

The Set Up screen shown in Figure 1-26 will analyze all the fire hydrants in your model to calculate the fire flow available at each hydrant (one at a time) such that the pressure in

the system is above 20 psi at all locations. Normally the minimum pressure occurs at the fire hydrant but it may occur at a different location. If this happens the Fire Flow Report shown above will show 2 additional columns of calculations showing the reduced fire flow and the node location where the minimum pressure occurs.

1-6 Demo1-4 – EPS (Demo EPS.P2K)

It is a simple matter to set up an Extended Period Simulation (EPS) using the Baseline Data for the system. Care should be taken to initially clear any Change Pattern Data

before setting up the EPS (select  (KYnetic) or **Setups and Defaults/Change Patterns** (Classic) and click on the **Clear** button). To run an EPS go to the EPS Setup Screen  (KYnetic) or **System Data/EPS** (Classic) and enter data as shown in Figure 1-28. For a municipal water distribution system such as this example a 24-hour period using a 1-hour computational period is a common selection although a shorter time period may be needed if there are numerous events during the period (tanks filling or emptying and pumps turning on and off).

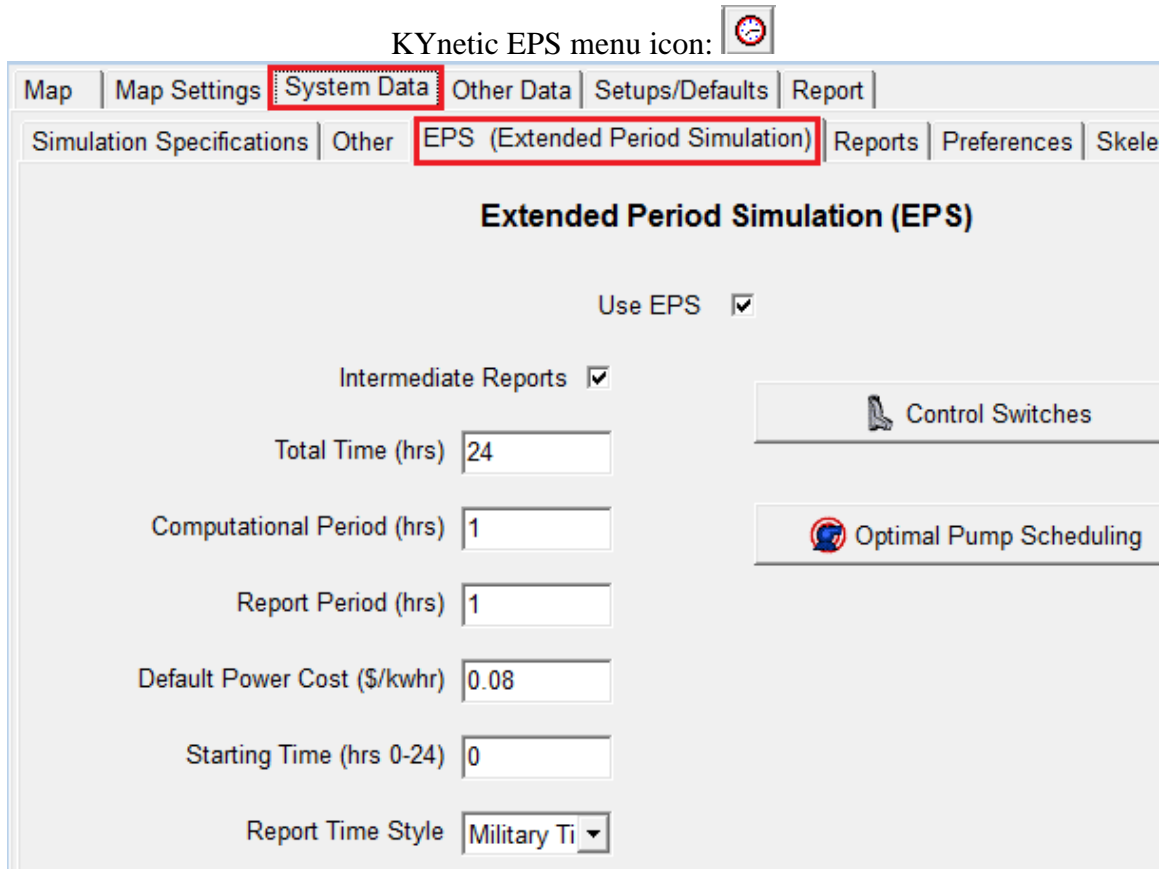




Figure 1-28 EPS Setup Screen - Demo1-4

Name	T-1	Name	T-2
Tank	Tank	Tank	Tank
Elevation	630	Elevation	625
Mx Level	755	Mx Level	755
Mn Level	735	Mn Level	730
Initial	750	Initial	749
Inflow	0	Inflow	0

Tank Data: Classic

Node Type	Tank Fixed Diameter	Node Type	Tank Fixed Diameter
Name	T-1	Name	T-2
Elevation	630	Elevation	625
Max Level	755	Max Level	755
Min Level	735	Min Level	730
Initial Level	750	Initial Level	749
Inflow	0	Inflow	0
Title	South Tank	Title	North Tank
Diameter	35	Diameter	35
On/Off		On/Off	

Tank Data: KYnetic

Figure 1-29 Tank EPS Data - Demo1-4

For an EPS the maximum (Mx) and Minimum (Mn) levels are significant items. This data shown in Figure 1-29 will cause the tanks to shutdown if either of these limits is reached. For municipal water systems the demands will vary hour by hour because of the variation in the diurnal curve as shown in Figure 1-30. This curve developed by AWWA based on field measurements provides a rational basis for varying the demands over a 24-hour period (Demand Pattern). Pipe2018 has the capability to set up, save and load Demand Patterns. An example pattern based on the AWWA curve is available (click the Load button in Demand Pattern menu and select AWWA.dmt). This Demand Pattern file is loaded as shown in Figure 1-30 and used for this example.

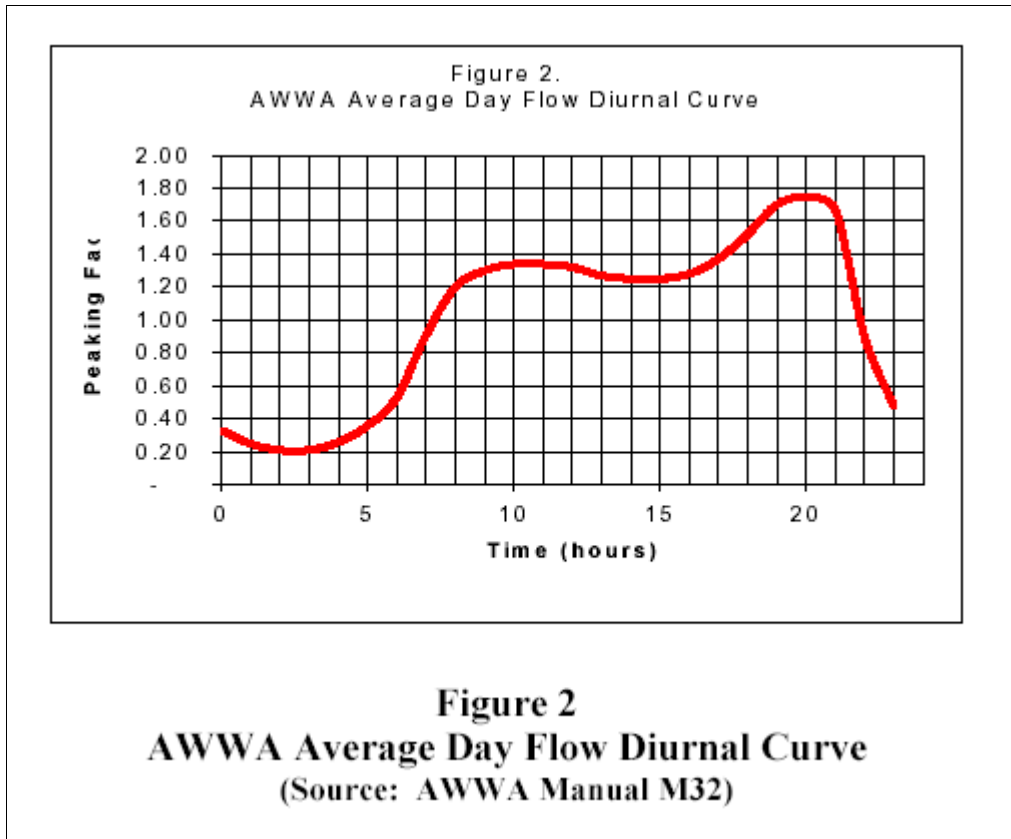


Figure 1-30 Diurnal Curve Data From AWWA - Demo1-4

KYnetic Demand Pattern table icon:

Pipe Type | Fittings | Sliders/Precision | Change Patterns | Demand Patterns | Table Setup

Load | Save | Clear | Total Time | Time Inc

Pattern Name | Global Demand Factor

Time/Change	0	1	2	3	4	5	6	7
Power Cost								
Residential								
Type 1	0.33	0.25	0.21	0.21	0.26	0.36	0.53	0.91
Type 2								
Type 3								

Figure 1-31 Demand Pattern EPS Data - Demo1-4

For Demo1-4 the pump is always on. For an EPS the pump status can be controlled either by inputting Change Data which can be used to turn the pump on or off at designated times or by a Control Switch which can be used to control the pump on/off status based on pressures or tank levels. This EPS example illustrates the tank action based only on demand variations.

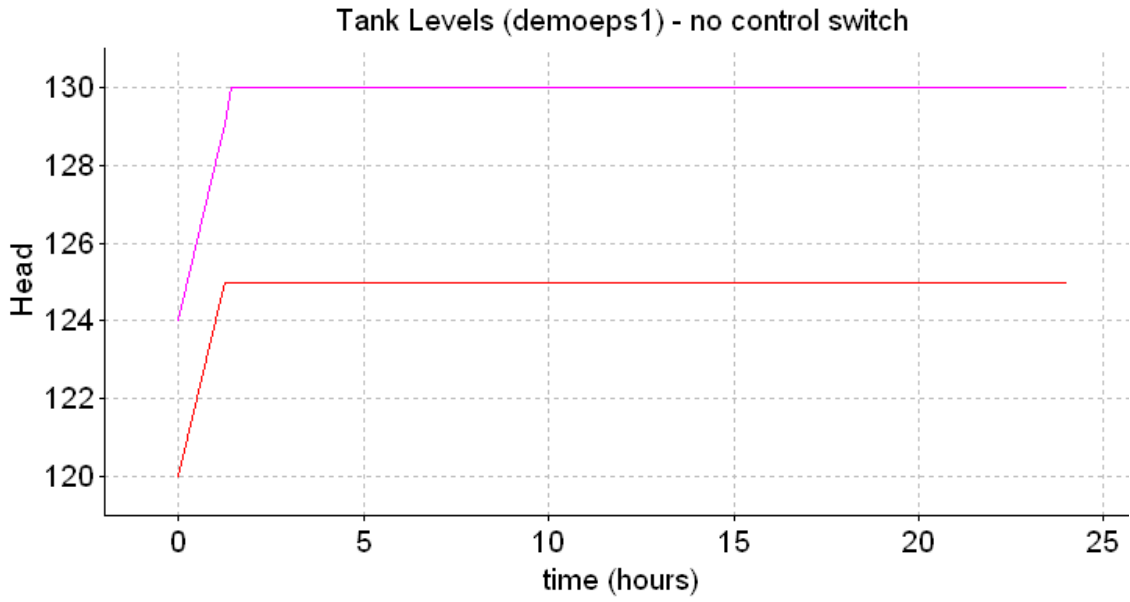


Figure 1-32 Tank Levels - Demo1-4

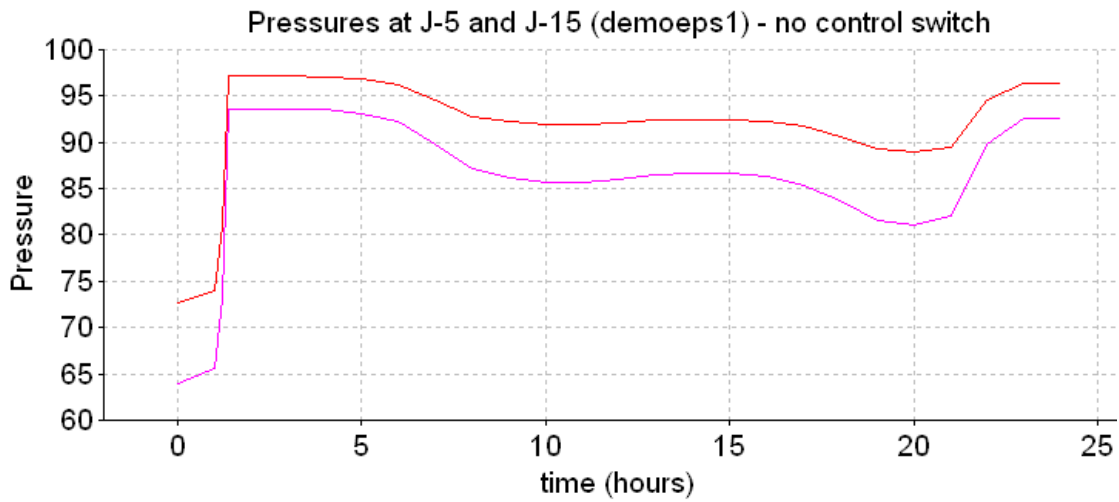


Figure 1-33 Pressures - Demo1-4

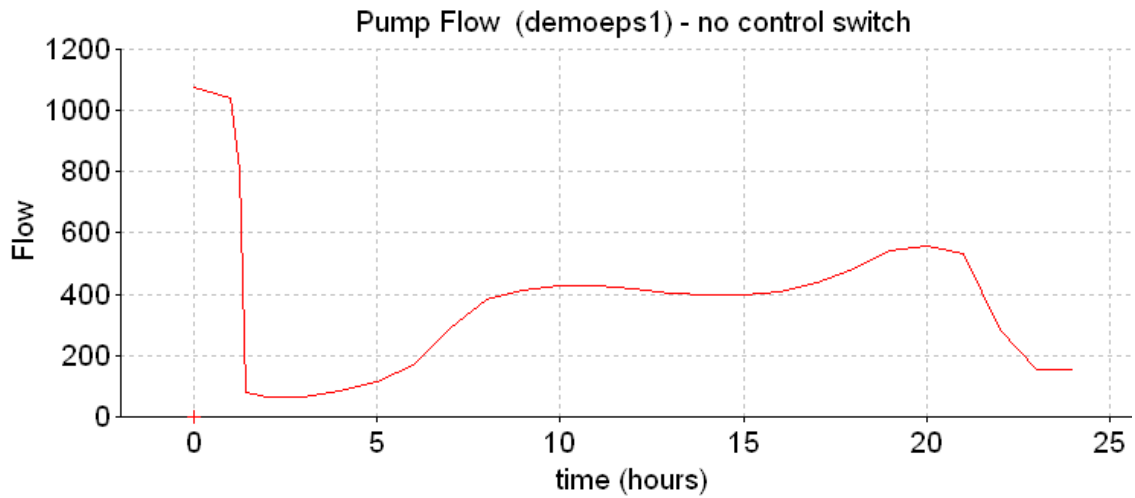


Figure 1-34 Pump Flow - Demo1-4

Figures 1-32 through 1-34 show results for this simulation. Figure 1-32 shows that the tanks are completely filled within the first 2 hours and stay full for the rest of the simulation. This causes the pump to run at a low flow and high head and produces a substantial pressure increase when the tanks fill as shown in Figures 1-33 and 1-34. Figure 1-35 shows the report on the pumping cost from the tabulated report. To obtain this report you must enter a cost/kilowatt hour as shown in Figure 1-28.

```



*****
TOTAL POWER COST($ ) FOR THIS SIMULATION =      36.30
*****

```

Figure 1-35 Power Costs - Demo1-4

1-6 Demo1-5 – EPS (Demo EPS Control Switch.P2K)

The results from Demo1-4 illustrate a situation which would be unacceptable for a municipal water system. The tanks cannot remain full because of water quality concerns. This example (Demo1-5) illustrates controlling the pump using the level of the water in Tank 1 (T-1). For this illustration we add a pump control switch which will turn the pump off when the water level exceeds 753 feet hydraulic grade (or 123 feet based on ground elevation). This is 2 feet below the maximum level (125 feet). The pump will then come on when the level drops below HGL = 737 feet (107 feet). The setup for this Control

Switch  +  Control Switches (KYnetic) or **Other Data/Control Switches** (Classic) is shown in Figure 1-36.

Switch Units												
HGL (ft or m)												
controlled element	is	on/off	when	sensing node	is	below/between	low level	and	on/off	when	above	high level
Pump-1	is	on	when	T-1	is	below	737	and	off	when	above	753

Figure 1-36 Control Switch Data - Demo1-5

The results for this EPS are shown in Figures 1-37 thru 1-39. As can be seen the pump switches off at around 2 hours and turns back on at around 14 hours. This results in less pressure fluctuations and a significantly reduced power cost (Figure 1-40)

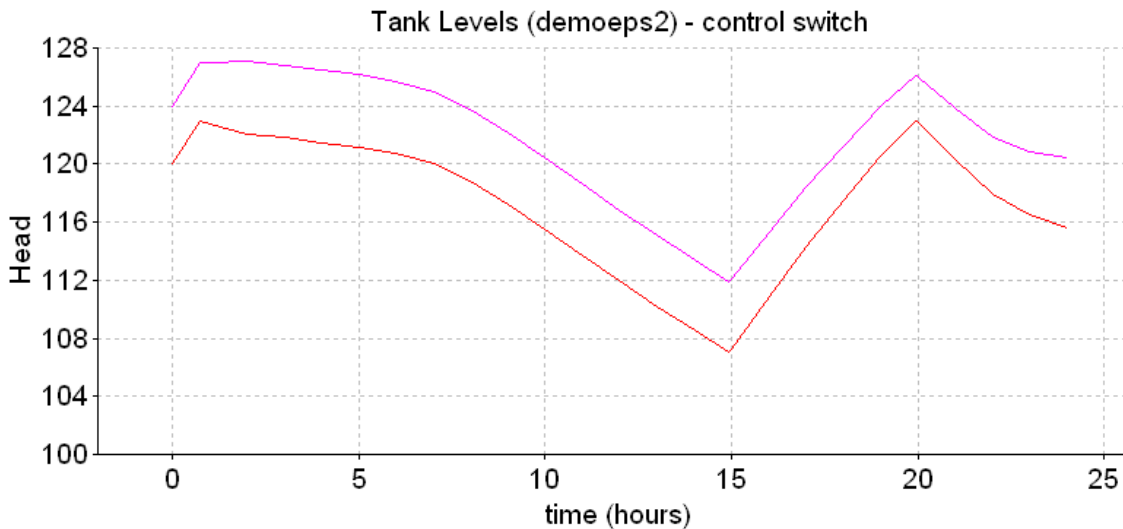


Figure 1-37 Tank Levels - Demo1-5

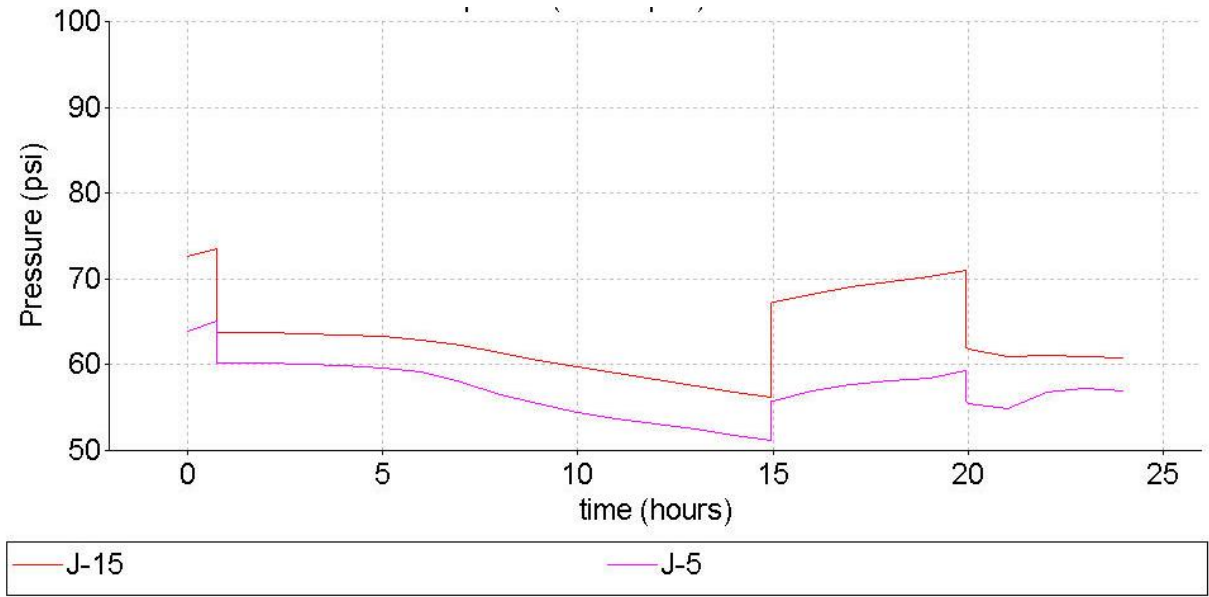


Figure 1-38 Pressures - Demo1-7

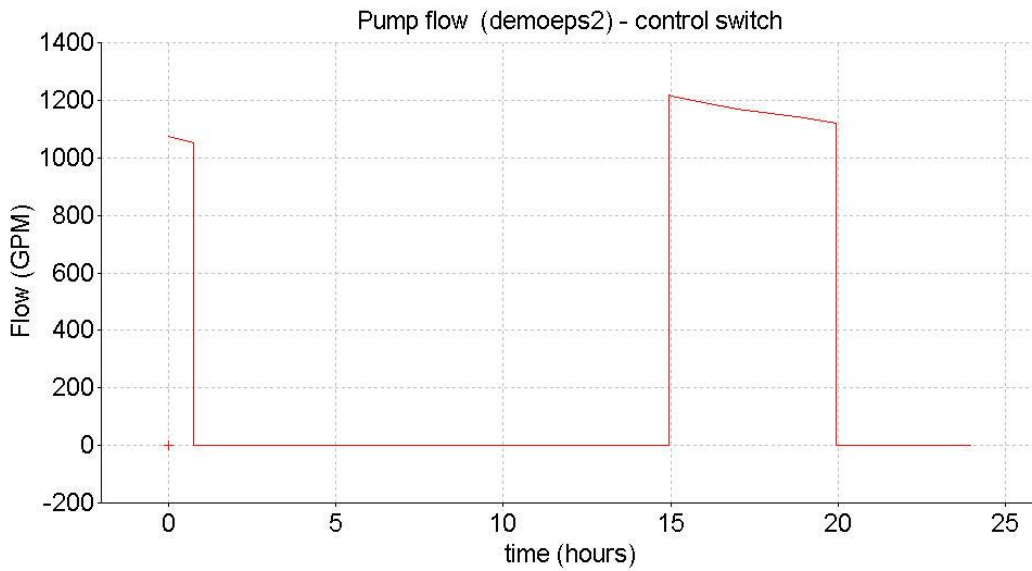


Figure 1-39 Pump Flow - Demo1-5

```

*****
TOTAL POWER COST($) FOR THIS SIMULATION =    23.42
*****

```

Figure 1-40 Power Costs - Demo1-5

1-6 Demo1-6 - Water Quality Simulation (Demo Water Quality.P2K)

A water quality analysis is run using an EPS file. This is to determine the variance in the water quality parameters over a time period (generally 24 hours). Only one screen of additional data is required to set up the water quality analysis as shown below. Click on the KYnetic Analysis menu as shown below or Other Data | Quality (Classic) to see the Quality input menu.



Global Bulk Reaction Rate	-1.25	Quality Simulation Time	144	
Global Wall Reaction Rate	-0.8	Time Units	Hours	
Order of Reaction - Bulk	1	Quality Time Step	0.01	Update Tables
Order of Reaction - Wall	1	Quality Parameter	Chemical	
Order of Reaction - Tank	1	Chemical/Tank Name	chlorine	
Limiting Potential	0	Attribute used for nodes "Initial Concentration"	Initial Conc	
Roughness Correlation	0	Attribute used for nodes "Initial Age"	Initial Age	
Quality Tolerance	0	Attribute used for pipes "Bulk Reaction Rate"	Bulk Rate	
Diffusivity (sqr ft/sec)	1.3E-8	Attribute used for pipes "Wall Reaction Rate"	Wall Rate	

Tank Source Data

Tank	Initial Concentration	Pattern	Bulk Reaction Rate	Mixing Model	Volume
T-1	0.3			0	0
T-2	0.3				

Node Source Data

Node	Initial Concentration	Pattern	Type

Reservoir Source Data		
Reservoir	Initial Concentration	Pattern
R-1	2	

Pattern Data (Multipliers)								
Pattern #	1	2	3	4	5	6	7	
1								
2								

Figure 1-41 Water Quality Data


The Bulk and Wall Reaction Rates are set for all pipes using the global value shown rather than averaging values for each pipe. A Simulation Time of 144 hours is chosen to provide ample time for the solution to reach a repeatable condition. For this example a Chemical analysis is chosen to determine the chlorine residuals. We could choose to calculate the age of the water (select Age) or trace the origin of the water (select Trace). One additional useful data input is the Initial Concentration of chlorine at each node. This can be assigned an initial value of zero. However, a reasonable estimate of this value will provide the solution more quickly and accurately. Since the chlorine is supplied at 2 ppm, a value of 1 ppm is used for the initial concentration and this data is assigned by using the Gbox (Group Mode) to select the entire system and the Edit Node Set to assign a value of 1.0 to the Initial Concentration. When this is done the User Data for each node should display this data as shown below:

The screenshot shows two panels. On the left is the 'User Data' panel with fields for Constraint Group, Initial Conc (set to 1), Initial Age, Manufacturer, and Model. On the right is a node properties table for node J-11. The 'Initial Conc' field in the table is highlighted with a red box and contains the value '1'. At the bottom right, there is a toolbar with icons for various functions, including one circled in red.

Node Type	Junction Single Dem
Name	J-11
Elevation	610
Demand	45
Demand Type	1
Title	
Ignore Changes	<input type="checkbox"/>
Constraint Group	
Initial Conc	1
Initial Age	

Classic - KYnetic

Figure 1-42 User Data with Initial Concentration

The Water Quality Analysis is then run by selecting  (KYnetic) or Analyze (Classic) and Analyze | Water Quality.

Once the analysis is completed the results are reviewed. Figure 1-43 shows the results for the minimum and maximum chlorine levels. This is obtained by selecting Chlorine in the Results Selector – bottom right of program window and Node Results - Min and Max under Labels.

A plot of the variations in the chlorine residuals at various nodes can be shown as illustrated in Figure 1-44.

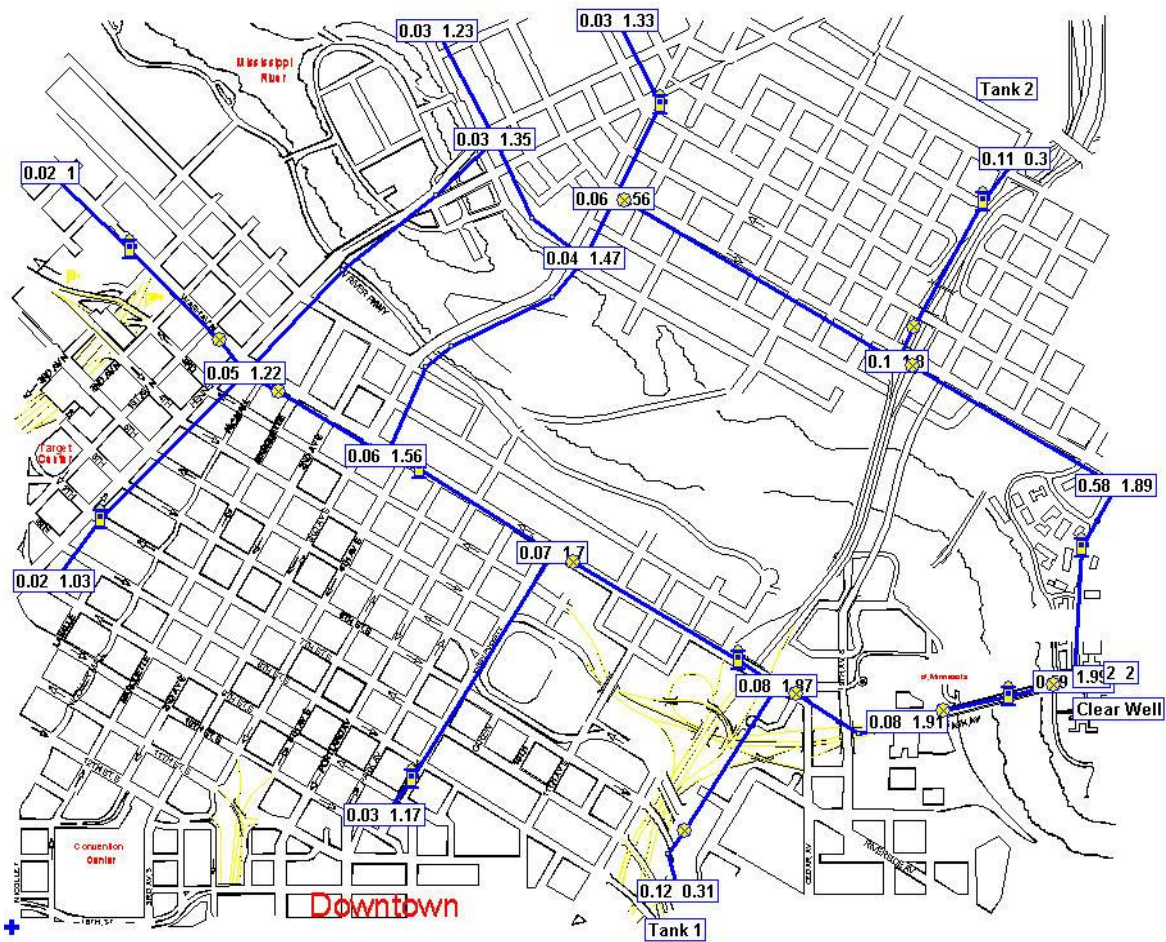


Figure 1-43 Min/Max Chlorine Residuals

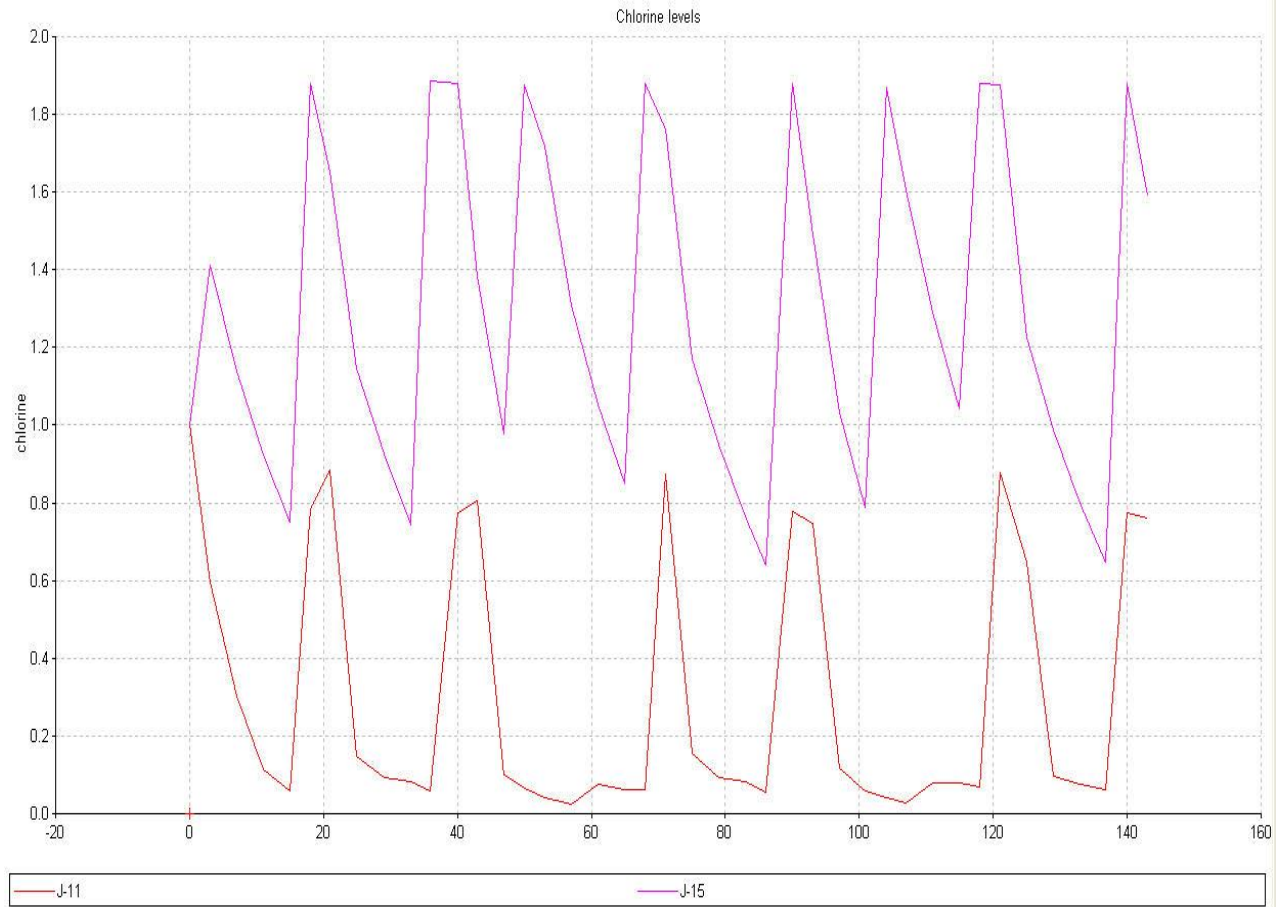


Figure 1-44 Chlorine Residuals at Selected Nodes

1-6 Demo1-7 - Optimized Calibration (Demo Calibration.P2K)

The section describes the original input approach for Optimized Calibration. A Calibration Wizard is also available. Figure 1-45 shows a network schematic with the test results of four fire flow tests displayed. This fire flow test data provides the basis for performing a calibration of the distribution system. The calibration will determine the optimum value for pipe roughnesses for various groups of pipes.

FIRE FLOWS AND RESIDUAL PRESSURES FOR CALIBRATION (DEMOCAL)

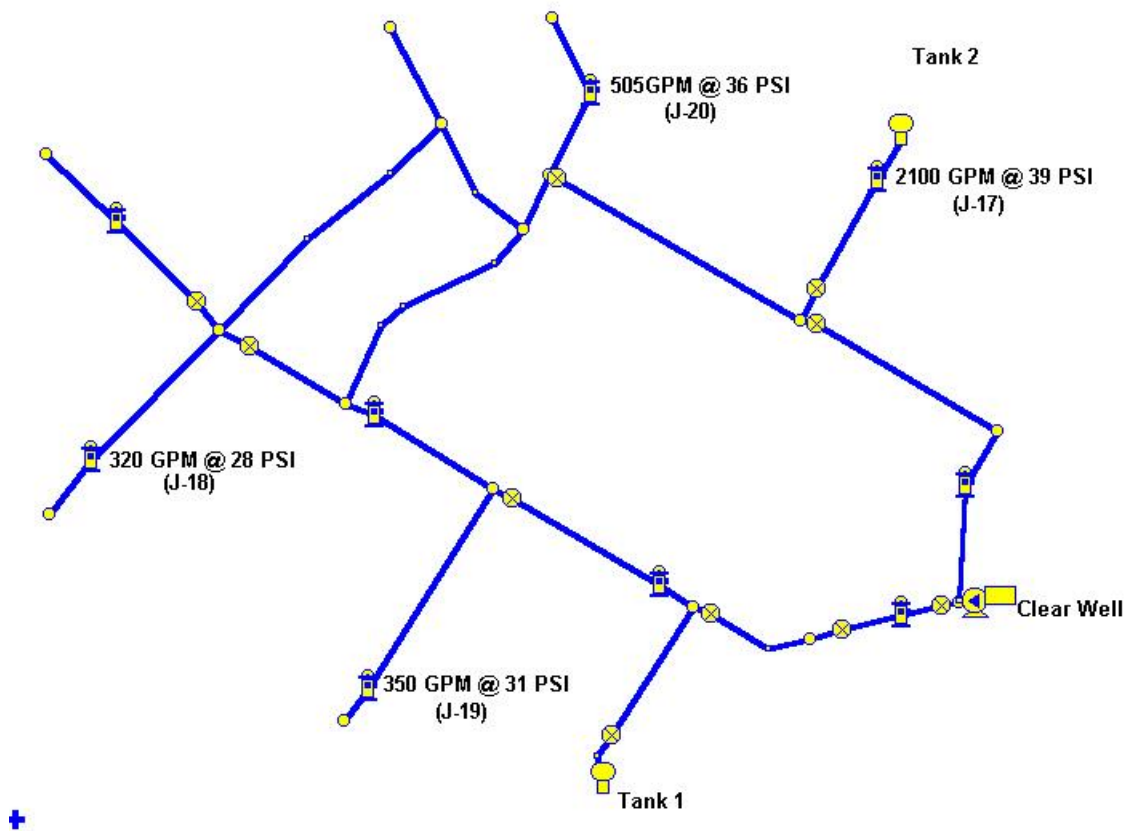


Figure 1-45 Fire Flow Test Results

The test data include the residual flow and pressure for each of the tests. For the calibration these four hydrants were converted to junctions as required to set up the calibration data. For this demonstration, it is assumed that the boundary conditions (tank levels, demands, pump status, etc.) for each fire flow test were the same and that the baseline demands and the tank levels are those used for the demo model.p2k file and shown in Figure 1-46. Thus, it is not necessary to enter change data for the four separate fire flow tests. The only additional data required is the Calibration Data shown in Figure 1-47.

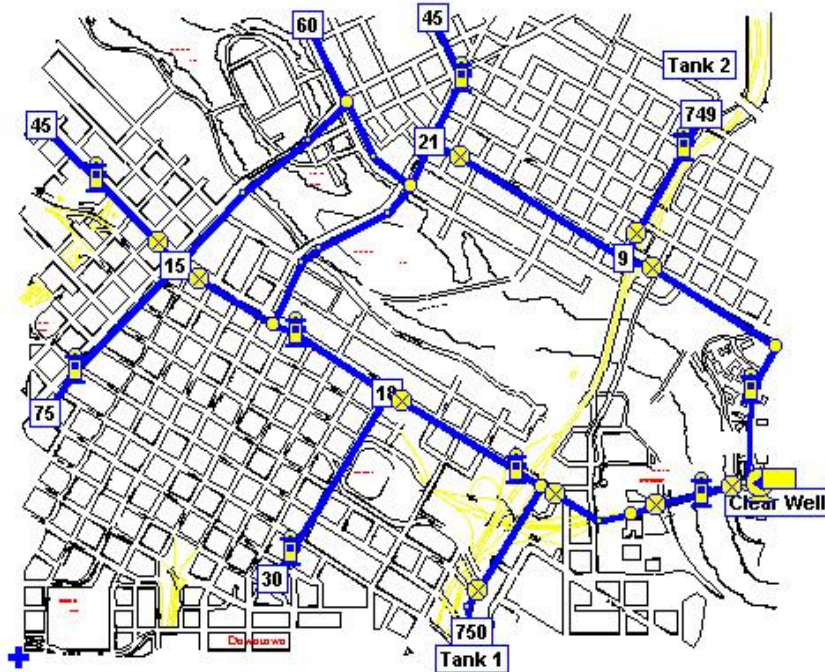
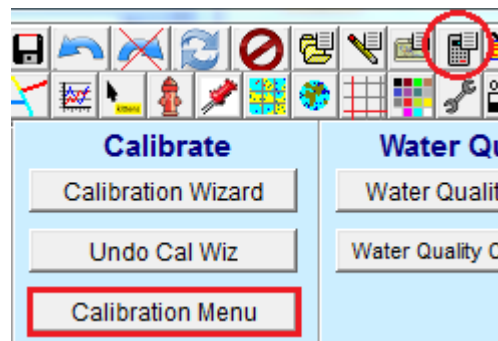


Figure 1-46 Tank Levels and Baseline Demands for Calibration



KYnetic Calibration menu:

Map | Map Settings | System Data | Other Data | Setup/Defaults | Report

Control Switches | Constraints | Calibration | Quality | Meters | Library Elements | Active Valves

Attribute used for "Pipe Type"

Demand Tolerance % Fireflow Tolerance %

Roughness Calibration
 Adjust Roughness Coefficients
 Adjust Aging Factors

Junction Pressure Data			Junction Flow Data			Roughness Bounds		
CASE	JUNCTION	PRESSURE	CASE	JUNCTION	FLOW	PIPE TYPE	UPPER	LOWER
1	J-17	39	1	J-17	2100	0	140	100
2	J-20	36	2	J-20	505	1	140	80
3	J-19	31	3	J-19	350	2	140	90
4	J-18	28	4	J-18	320	3	140	100

Figure 1-47 Fire Flow and Calibration Data

The roughness bounds were defined for four Calibration Groups selected using various diameters as follows:

Group Diameter

0	12
1	6
2	8
3	10

Two calibration analyses were run.

For the first calibration a 5% tolerance was introduced for the fire flows. This means that the fireflows can be +/- 5% of the measured residual flow and accounts for a small error in this measurement. The calibration run produced a calibration where the optimal pressure differed from the measured pressure by only 1.4% where the difference is greater than 1.6% for the uncalibrated model. The results for the first case are shown in Figure 1-48.

For the second case, a zero percent fireflow tolerance was used and, as expected, a larger difference of 4.8% was obtained. These results are shown in Figure 1-49.

```

SUMMARY OF RESULTS :
-----

Percent Deviation between MEASURED and TARGET Values = 0.832

OPTIMAL values for the Decision variables:

Hazen William coefficients: for group number 0 = 100. [140.0< >100.0]
Hazen William coefficients: for group number 1 = 105. [140.0< > 80.0]
Hazen William coefficients: for group number 2 = 90. [140.0< > 90.0]
Hazen William coefficients: for group number 3 = 110. [140.0< >100.0]

No demand adjustments are made.
Demand Tolerance is meant for re-distributing
demands among nodes of diff demand types, keeping
the total demand constant. There must be at least
TWO types of demands to use this feature.

Junction (Fire) Flow(s) for Change 1 are INCREASED by 5.00%
Junction (Fire) Flow(s) for Change 2 are DECREASED by 4.68%
Junction (Fire) Flow(s) for Change 3 are INCREASED by 1.45%
Junction (Fire) Flow(s) for Change 4 are INCREASED by 5.00%

Measured and Target pressures (psi or kPa):

TEST      NODE      MEASURED      OPTIMAL
CASE      NUMBER    PRESSURE      PRESSURE
-----
1         J-17      39.0          39.2
2         J-20      36.0          35.3
3         J-19      31.0          31.2
4         J-18      28.0          28.2

```

Figure 1-48 First Case Results (5% fire flow tolerance)

SUMMARY OF RESULTS :

Percent Deviation between MEASURED and TARGET Values = 4.740

OPTIMAL values for the Decision variables:

Hazen William coefficients: for group number 0 = 100. [140.0 < > 100.0]
Hazen William coefficients: for group number 1 = 103. [140.0 < > 80.0]
Hazen William coefficients: for group number 2 = 90. [140.0 < > 90.0]
Hazen William coefficients: for group number 3 = 100. [140.0 < > 100.0]

Measured and Target pressures (psi or kPa):

TEST CASE	NODE NUMBER	MEASURED PRESSURE	OPTIMAL PRESSURE
1	J-17	39.0	40.7
2	J-20	36.0	32.6
3	J-19	31.0	31.1
4	J-18	28.0	30.3

Figure 1-49 Second Case Results (0% fire flow tolerance)

Surge Demonstrations and Example Data Files

- 1 **Pump Rundowns Using Pump Head/Flow Table (*Pump Run Down.P2K*)**
 - 1-1 2-second rundown with CV
 - 1-2 2-second rundown without CV (flow reversal)
 - 1-3 2-second rundown with Pressure Sensitive Demands
- 2 **Pump Trip Using Pump File (*File Pump.P2K*)**
 - 2-1 Trip with CV
 - 2-2 0.5-second rundown with CV
 - 2-3 Trip with and without CV
 - 2-4 10-second rundown comparing file and table
 - 2-5 Controlled shutdown – pump and control valve
- 3 **Pump Startups Using Pump File (*Pump Startup.P2K*)**
 - 3-1 2-second startup – one and two pumps
 - 3-2 10-second startup – one and two pumps
- 4 **Fixed and Modulating Regulating Valves (*Regulator.P2K*)**
 - 4-1 No modulation (Regulating Valve)
 - 4-2 Modulation using Tool and Active Valve
- 5 **Compressor and Bladder Closed Surge Tanks (*Bladder Tank.P2K*)**
 - 5-1 Compressor surge tank – 40 cubic feet initial air
 - 5-2 Compressor surge tank – compare 30 and 40 cubic feet
 - 5-3 Bladder tank – precharge and sizing tool – 40 cubic feet initial air
- 6 **Valve Closures (*Altitude Valve.P2K*)**
 - 6-1 2-second closure
 - 6-2 20-second closure
- 7 **Relief Valve to Control Pressure Surge Due to Valve Closure (*Pressure Relief Valve.P2K*)**
 - 7-1 Add relief valve and provide data
- 8 **Hydrant Operations (Startup and Shut Down) (*Hydrant Open.P2K*)**
 - 8-1 Hydrant opens in 2 and 10 seconds
 - 8-2 Hydrant closes in 2 and 10 seconds
- 9 **Simulated Line Break Using Rupture Disk (*Rupture Disk.P2K*)**
 - 9-1 Fixed demands
 - 9-2 Pressure sensitive demands

I. Demo1 – Municipal Water Distribution System

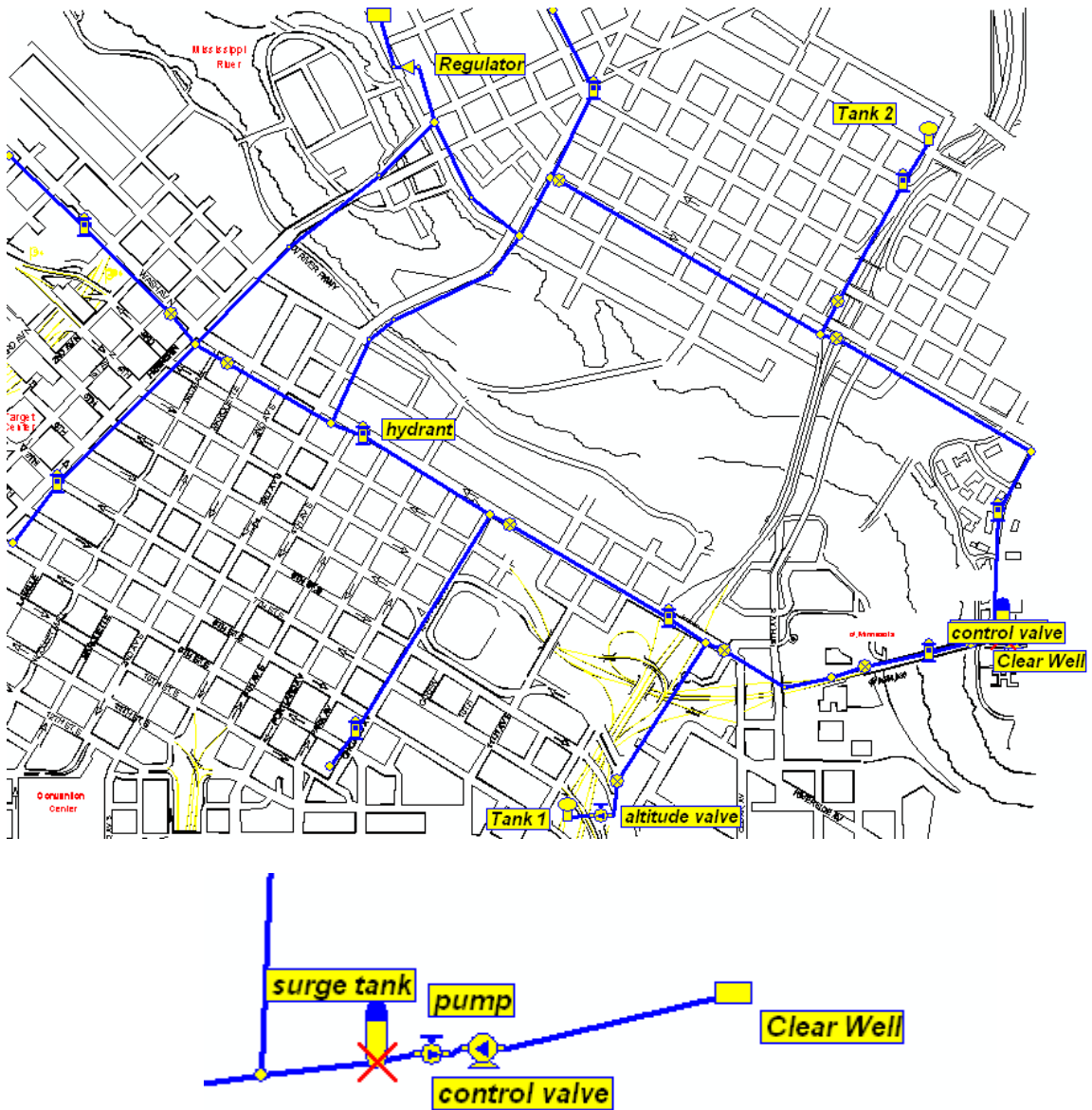


Figure 1 Schematic for Demo1I

The system above is used to illustrate a number of surge analyses and features of the Surge program. The system is fed from a clearwell through a pump and a control valve. A surge tank is shown but will be activated only for examples illustrating the use of a surge tank. The elements noted are used to illustrate various transients and simulations

such as pump, valve, and hydrant operations. For example, the altitude valve leading to the overhead tank (Tank 1) is used to illustrate the effects of valve closure and the use of a pressure relief valve.

The screens below illustrate the data for some of the elements. The Pipe Type Table includes wave speed data which is assigned to each pipe as the pipe type is selected. Demands are assigned to various junctions. A summary of the pipe and junction data is presented in Appendix A along with schematics showing pipe and nodes names.

Figure 2 System Data

	Material	Rating	Nominal Diameter	Actual Diameter	Unit Cost	Reference Roughness	Estimated 10yr Roughness	Wave Speed
1	di	150	6			130	120	4200
2	di	150	8			130	120	4150
3	di	150	10			130	120	4100
4	di	150	12			130	120	4050

Figure 3 Pipe Type Table

Node Type	Active Valve
Name	AV-1
Elevation	610
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0
Bypass Resistance	0
Grade	-----
Direction	←
On/Off	✓
Cv	1000
Initial Ratio	1
Valve Type	Butterfly

Node Type	Active Valve
Name	AV-2
Elevation	630
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0
Bypass Resistance	0
Grade	-----
Direction	←
On/Off	✓
Cv	500
Initial Ratio	1
Valve Type	Gate

Active Valve data: Classic and KYnetic

Node Type	Regulator
Name	RV-1
Elevation	630
Title	
Direction	←
Setting	40
Cv	0
Type	PSV

Regulator Data: Classic and KYnetic

Figure 4 Valve and Regulator Data

1 Pump Rundowns Using Pump Head/Flow Table (*Pump Run Down.P2K*)

- 1-1 2-second rundown with CV
- 1-2 2-second rundown without CV (flow reversal)
- 1-3 2-second rundown with Pressure Sensitive Demands

For Case 1, a pump table is used to describe the pump and the data is presented in Figure 1-1. Case 1-1 is carried out using a 2-second pump rundown set up using change data shown in Figure 1-2. For Case 1-2 the check valve is removed and for Case 1-3 the analysis is carried out using Pressure Sensitive Demands. Results are shown in Figures 1-3 to 1-5.

Name	Pump-1	ID	1	Device Data		
Pump	Pump	Head	Flow	Eff%	CV Time	
Elevation	610	220	0	68	0.1	
Sp Ratio	1	200	600	77	CV Res	
		160	1200	70	0.05	
					Byps Res	
					1	
Pump Type <input checked="" type="radio"/> Table <input type="radio"/> File <input type="radio"/> Const <input type="radio"/> Rated					More Device Data Pump Res 0.05	
<input type="button" value="←"/> Single					<input checked="" type="checkbox"/> Check Valve <input type="checkbox"/> NonReopen CV <input type="checkbox"/> Bypass Line	

Pump Data - Classic

Node Type	Pump - Table
Name	Pump-1
Elevation	610
Title	
Parallel	Single
ID	1
Check Valve	<input checked="" type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0.1
CV Resistance	0.05
Bypass Resistance	1
Speed Ratio	1
Pump Resistance	0
Direction	
Grade	-----
On/Off	<input checked="" type="checkbox"/>

Pump Curves

1

Pressure Head

Head	Flow	Efficiency
220	0	68
200	600	77
160	1200	70
0	0	0
0	0	0
0	0	0
0	0	0

Pump Data - KYnetic
Figure 1-1 Pump Table Data (With CV)

Node Changes

Cut Copy Paste Clear

Time/Case	Value
0	s 1
1	s 1
3	s 0

Changes for Pump-1

Time	Change	Value
0	speed ratio	1
1	speed ratio	1
3	speed ratio	0

Pump Shutdown Data: Classic - KYnetic

Device Data

CV Time

CV Res

Byps Res

Check Valve

NonReopen CV

Bypass Line

Node Type	Pump - Table
Name	Pump-1
Elevation	610
Title	
Parallel	Single
ID	1
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>

No Check Valve in Pump: Classic – KYnetic

Demand Calculation

Fixed Demands

Fixed Demands

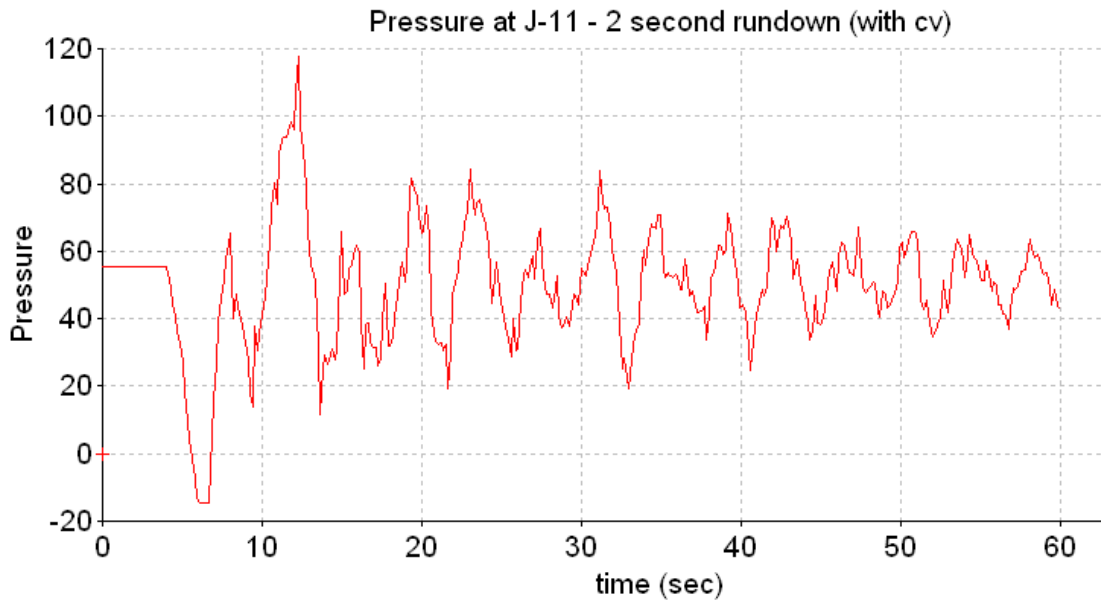
Pressure Sensitive

Do not calculate intrusion

Leakage Factor

Demand Modeling

Figure 1-2 Additional Data Screens



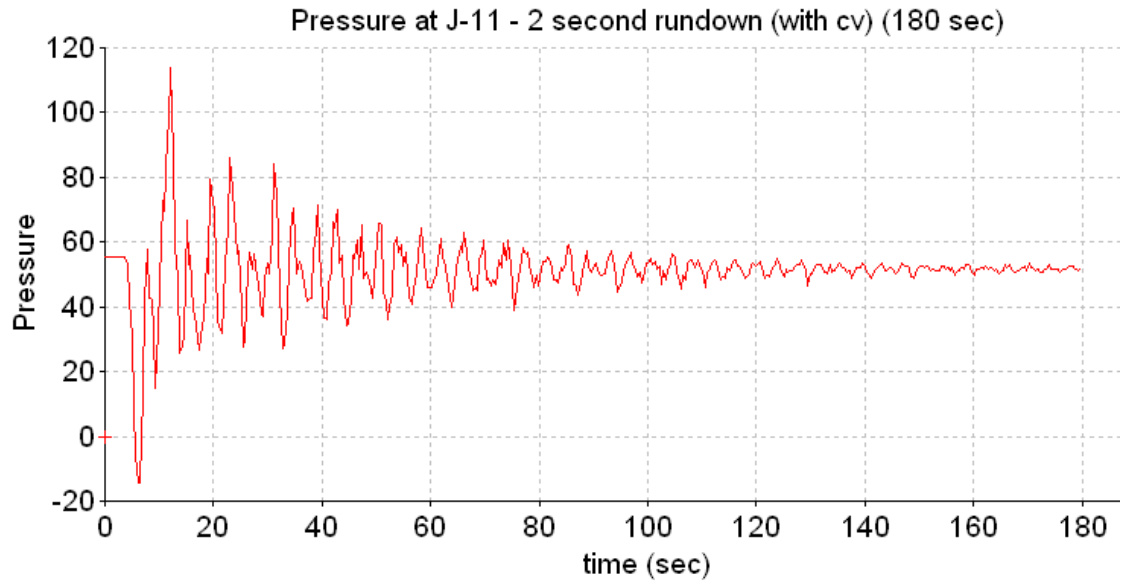


Figure 1-3 Results for Case 1-1

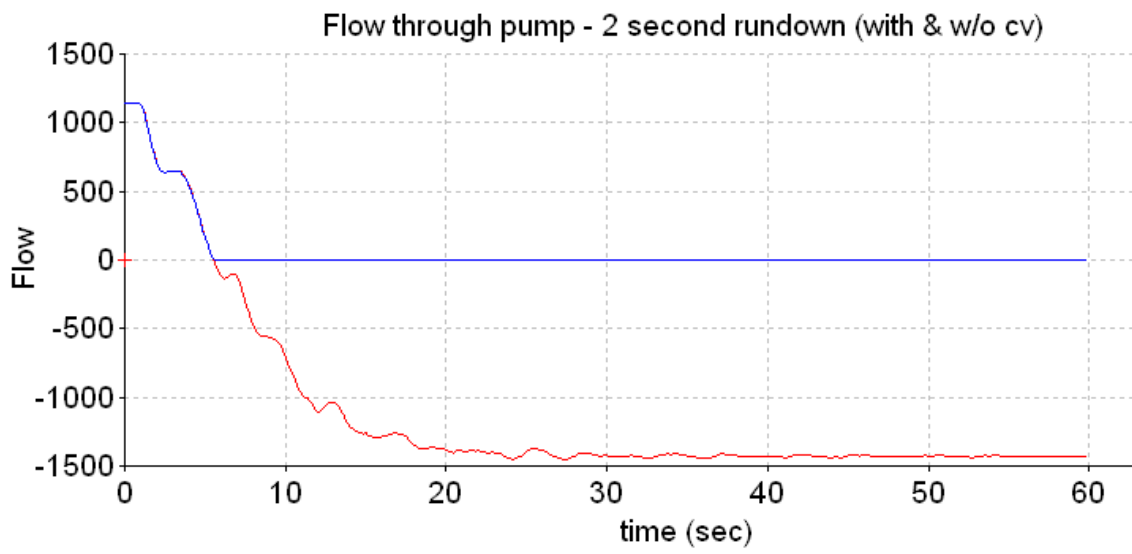
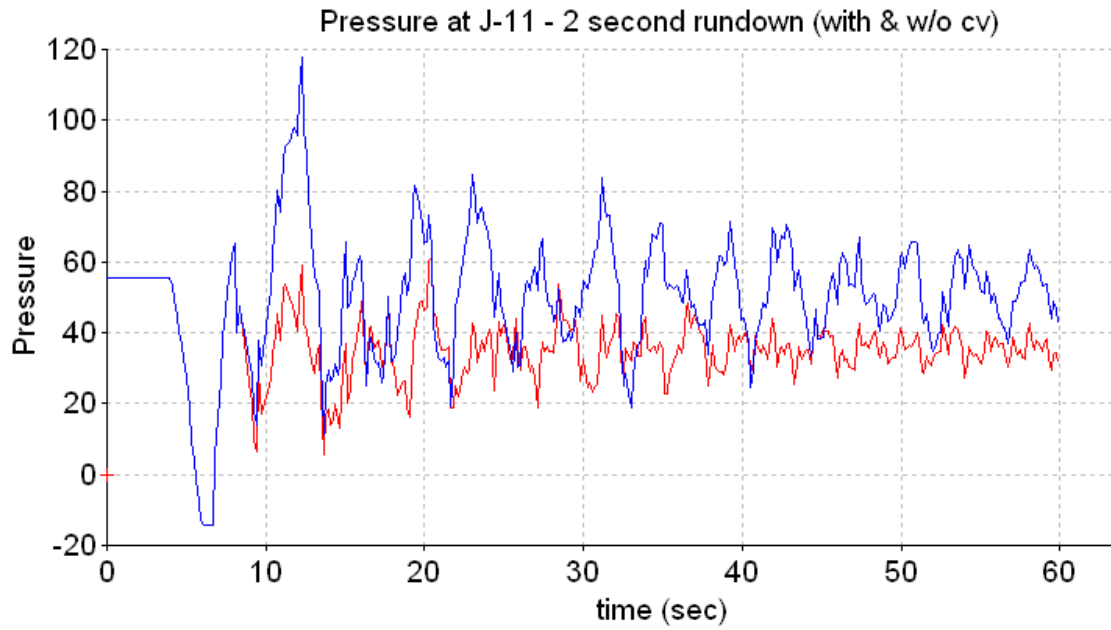


Figure 1-4 Results for Case 1-2

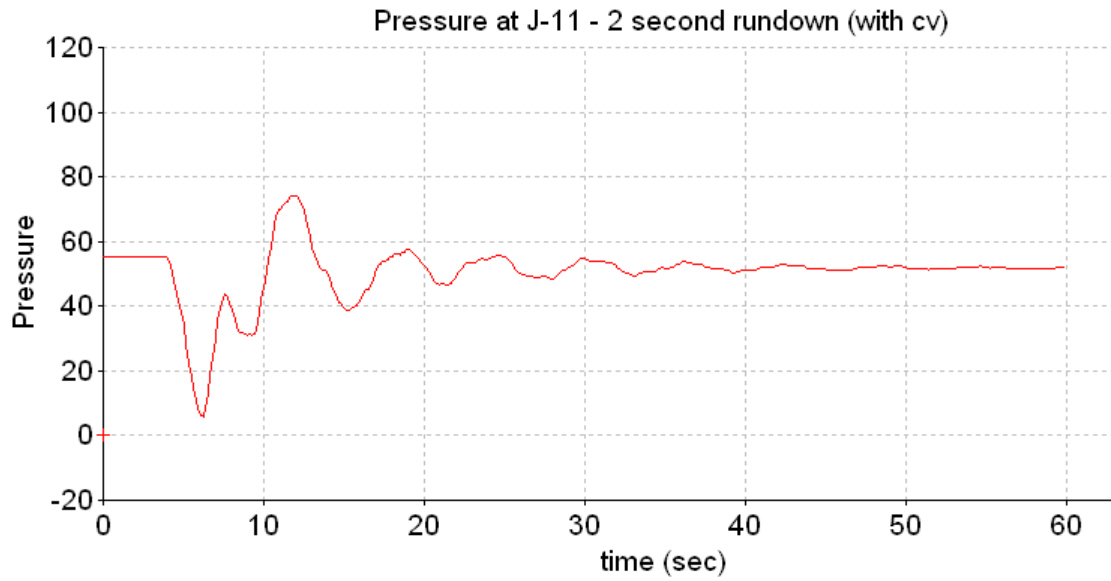


Figure 1-5 Results for 2-Second Pump Rundown with Pressure Sensitive Demands

2 Pump Trip Using Pump File (*File Pump.P2K*)

2-1 Trip with CV

2-2 0.5-second rundown with CV

2-3 Trip with and without CV



2-4 10-second rundown comparing file and table

2-5 Controlled shutdown – pump and control valve together

The screenshot shows the classic software interface for configuring a pump device. It is divided into three main sections:

- Name:** Name: Pump-1, Type: Pump, Elevation: 610, Sp Ratio: 1, Efficiency: 77%. Pump Type: File (selected), Single.
- Device Data:** CV Time: 0.1, CV Res: 0.05, File (1-8): 1, Rated Hd: 165, Rated Flw: 1140, Rated Spd: 1200, Inertia: 38. Check Valve: checked, NonReopen CV: unchecked, Bypass Line: unchecked.
- Node Changes:** A table with columns 'Time/Case' and 'Value'. The table contains two rows: (0, s) with value 1, and (1, t) with value Trip.

File Pump Data and Change Data – Classic

Node Type	Pump - File
Name	Pump-1
Elevation	610
Title	
Parallel	Single
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input checked="" type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0.1
CV Resistance	0.05
Efficiency %	77
Speed Ratio	1
Grade	----
File# (1-20)	1
Rated Head	165
Rated Flow	1140
Rated Speed	1200
Inertia	38
Pump Resistance	0.05
Bypass Resistance	0
Direction	
On/Off	

Changes for Pump-1		
Time	Change	Value
0	speed ratio	1
1	trip	Trip

File Pump Data and Change Data - KYnetic

Figure 2-1 Pump File Data and Pump Trip Data

Figure 2-1 shows the data screens used to describe the pump using a pump file. This approach is recommended for modeling a pump file because the rundown time is computed based on pump characteristics. In most cases users will only have head/flow data for normal operations. When using one of the Surge pump files for modeling a pump trip, it is recommended that the operating point for the initial steady state operations be used for the Rated Head and Rated Flow (1140 gpm @ 165 feet). This will assure that the starting conditions will match the one obtained using the head/flow curve. Surge tools are available for selecting the appropriate pump file and defining the inertia. The use of these tools is illustrated in Figure 2-2. It is assumed that the pump speed and efficiency are available data.

The Change Data setup for a pump trip initiated 1 second into the simulation is shown in Figure 2-1. A 60-second pressure history for node J-11 is shown in Figure 2-3 and the pump speed history is shown in Figure 2-4. This plot shows that the pump rundown occurs very rapidly over approximately 0.5 seconds. A principal benefit of simulating a pump trip is that the rundown time is calculated. Figure 2-5 compares the pressure history at J-11 for a pump trip and a 0.5-second pump rundown. The nearly identical results are due to two factors:

1. the rundown time of 0.5 seconds is very close to the predicted one,
2. the rapidly closing check valve presents abnormal pump operation.

Units English SI

Pump Speed N (rpm)

Flow Rate Q (gpm)

Pump Head h (ft)

Efficiency n (0 to 1)

Pump Power (HP)

INERTIA (lbft²)

Fairly Old Pumps

Small, light wt Pumps

Motor Inertia

Comb. Inertia (old pumps)

Comb. Inertia (small pumps)

Calculated Inertia is WR² (NOT GD²)

Specific Speed

Suggested Pump File

FORMULAE Pump Power

$$HP = \frac{\gamma Q_{GPM} H_p}{550\eta}$$

Inertia for fairly old pumps

$$I_{WR^2} = 0.6674 \times \left[\frac{HP}{(N/1000)^3} \right]^{0.9556}$$

Inertia for small, light wt pumps

$$I_{WR^2} = 0.6244 \times \left[\frac{HP}{(N/1000)^3} \right]^{0.844}$$

Motor Inertia

$$I_{WR^2} = 0.0648 \times \left[\frac{HP}{(N/1000)^3} \right]^{1.48}$$

Specific Speed

$$Spc.Speed = \frac{N \sqrt{Q_{GPM}}}{H_p^{3/4}}$$

Pump File	Spe.Speed-Eng	SpeSpeed-SI
1	1270	25
2	7600	147
3	13500	261
4	3725	72
5	4409	85
6	5203	101
7	6792	131
8	8764	169

Figure 2-2 Tools for Pump File Data

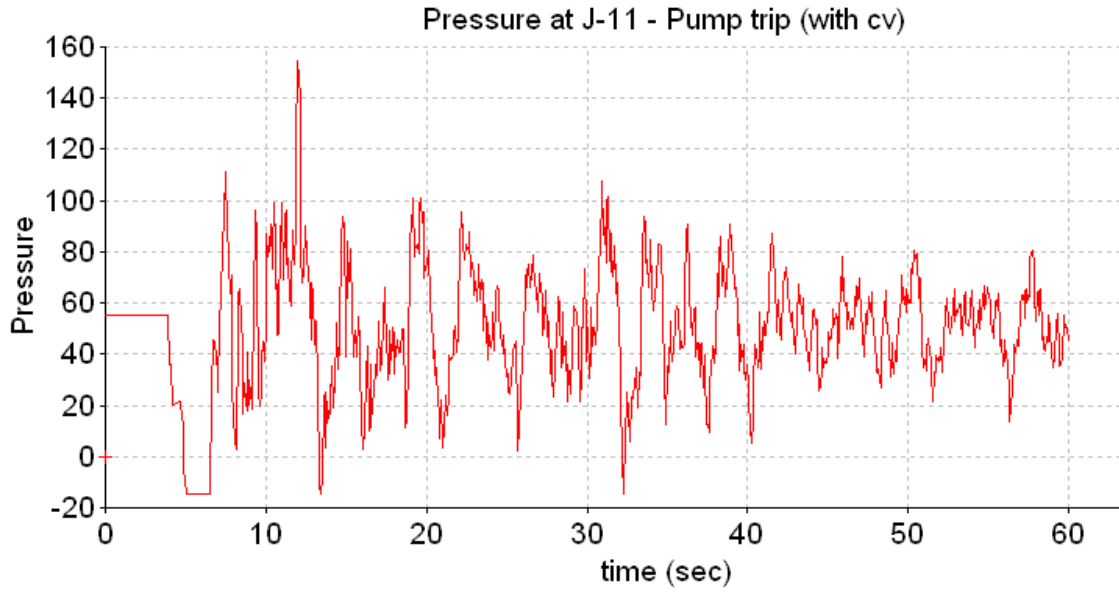


Figure 2-3 Results for Case 2-1

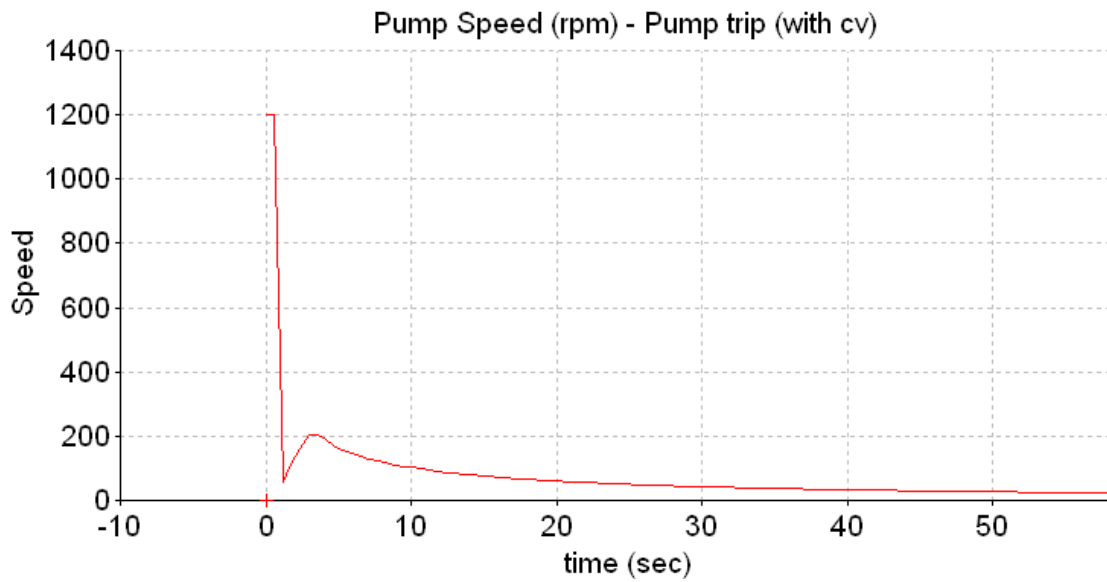


Figure 2-4 Results for Case 2-1

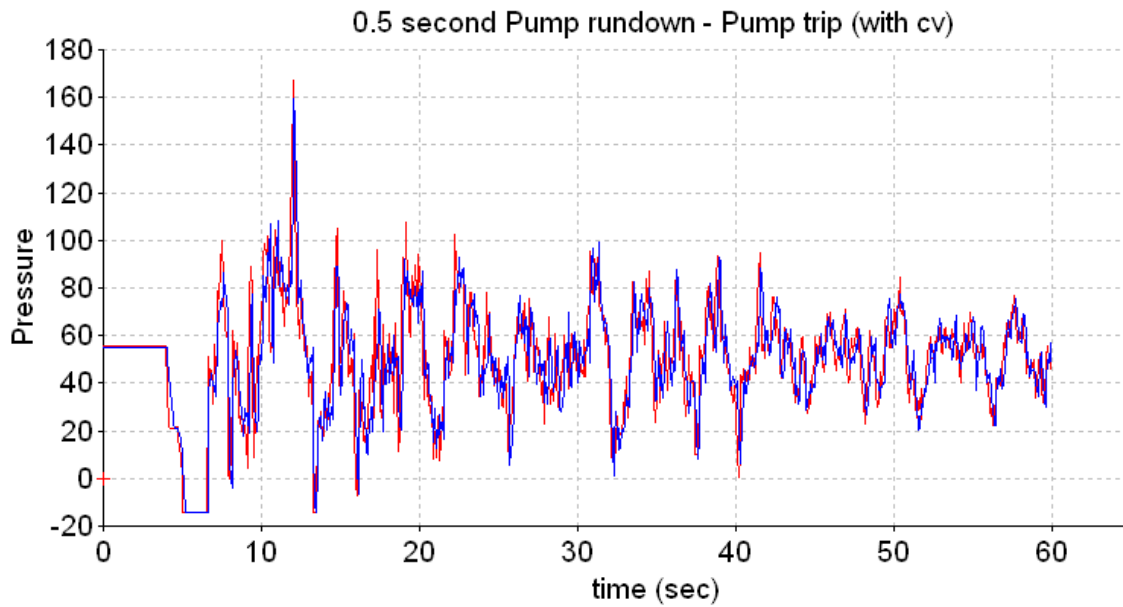


Figure 2-5 Results for Case 2-1 and 2-2

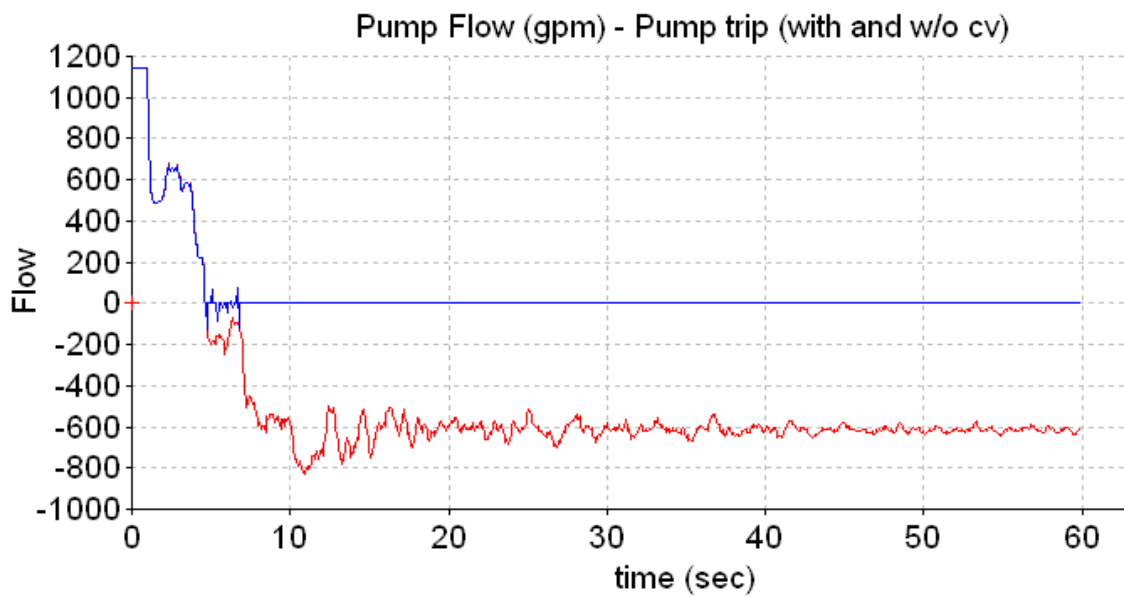


Figure 2-6 Results for Case 2-3

The Change Data setups for two additional simulations (Cases 2-4 and 2-5) are shown in Figure 2-7. The results for Case 2-4 are shown in Figure 2-8 and show the pressure history for J-11 for a 10-second rundown using both a pump head flow table and a pump file setup as described previously. The results illustrate 2 points:

- 1 the pump table and pump file give very similar results if abnormal pump operation is avoided,
- 2 pump shutdown can be controlled to limit the range of the pressure surges.

Case 2-5 illustrates a shutdown which combines the closing of a control valve and ramping down the pump (Figure 2-9). Surge can be used to determine effective techniques for turning off pumps.

Node Changes		
Cut Copy Paste Clear		
Time/ Case		Value
0	s	1
1	s	1
11	s	0

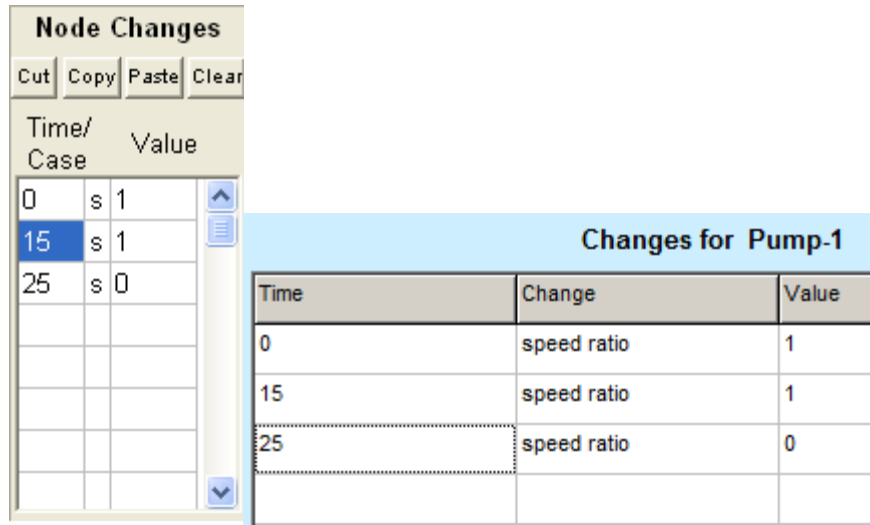
Changes for Pump-1		
Time	Change	Value
0	speed ratio	1
1	speed ratio	1
11	speed ratio	0

10-Second Pump Rund own: Classic - KYnetic

Node Changes		
Cut Copy Paste Clear		
Time/ Case		Value
0	r	1
25	r	0

Changes for AV-2		
Time	Change	Value
0	ratio	1
25	ratio	0

25-Second Valve Closure



10-Second Pump Rundown

Figure 2-7 Data Screens for Cases 2-4 and 2-5

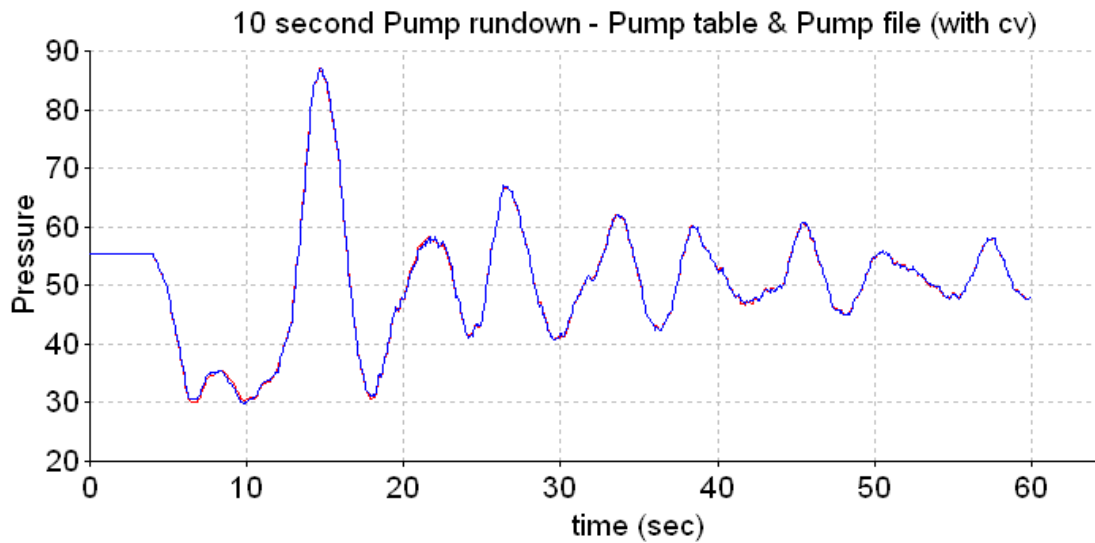


Figure 2-8 Results for J-11, Case 2-4

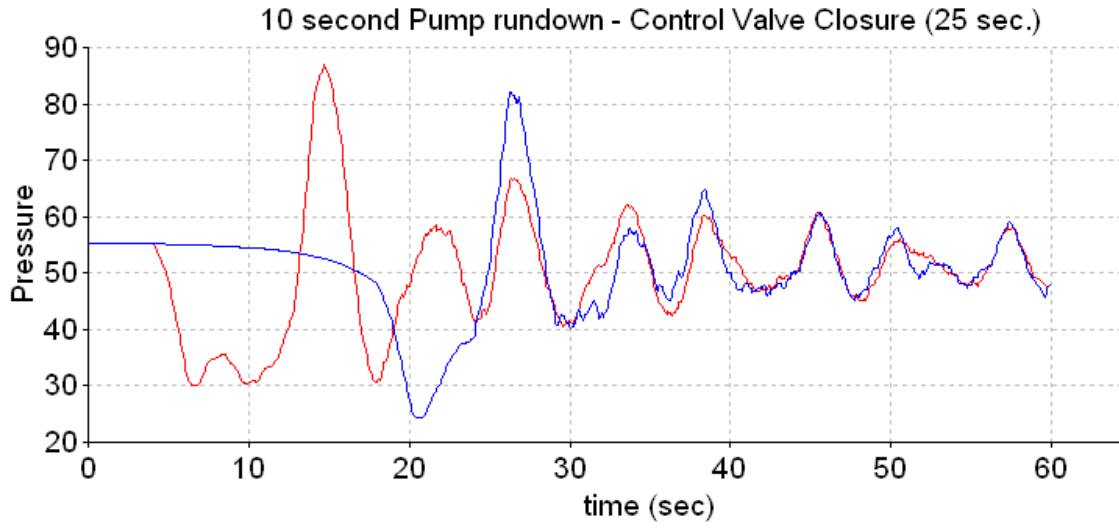
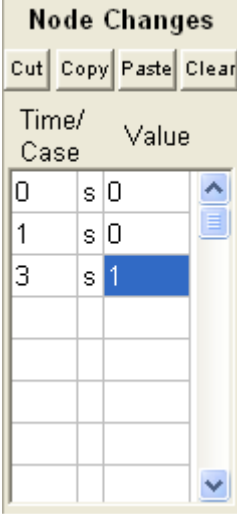


Figure 2-9 Results for J-11, Case 2-5 compared with Case 2-4

3 Pump Startups Using Pump File (*Pump Startup.P2K*)

3-1 2-second startup – one and two pumps

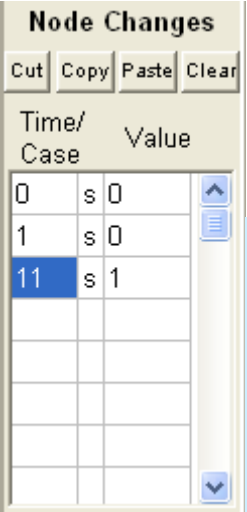
3-2 10-second startup – one and two pumps



The screenshot shows the 'Node Changes' dialog box with a table containing three rows. The third row is selected, showing a time of 3 seconds and a value of 1. To the right, a table titled 'Changes for Pump-1' shows the configuration for the pump at different time intervals.

Time	Change	Value
0	speed ratio	0
1	speed ratio	0
3	speed ratio	1

2-Second Startup



The screenshot shows the 'Node Changes' dialog box with a table containing three rows. The third row is selected, showing a time of 11 seconds and a value of 1. To the right, a table titled 'Changes for Pump-1' shows the configuration for the pump at different time intervals.

Time	Change	Value
0	speed ratio	0
1	speed ratio	0
11	speed ratio	1

10-Second Startup

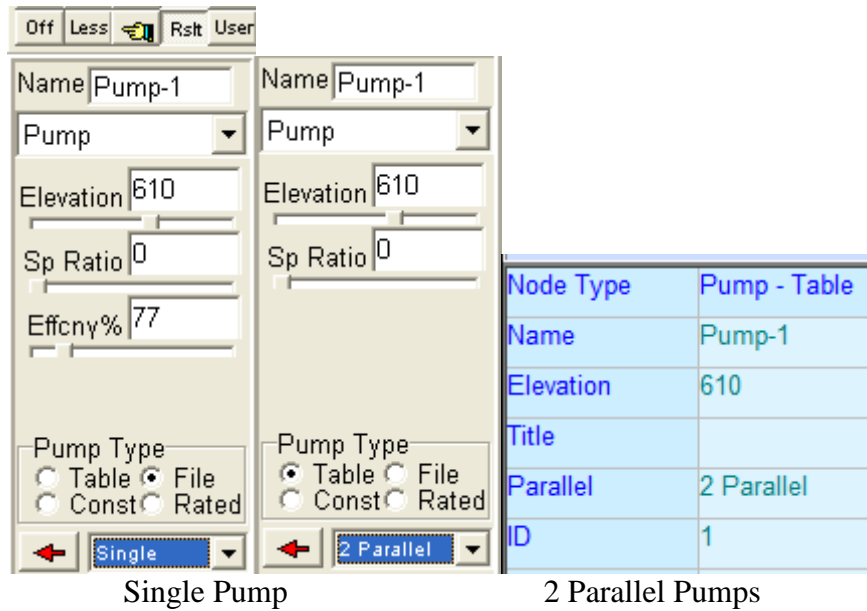


Figure 3-1 Data Screens for Cases 3-1 and 3-2

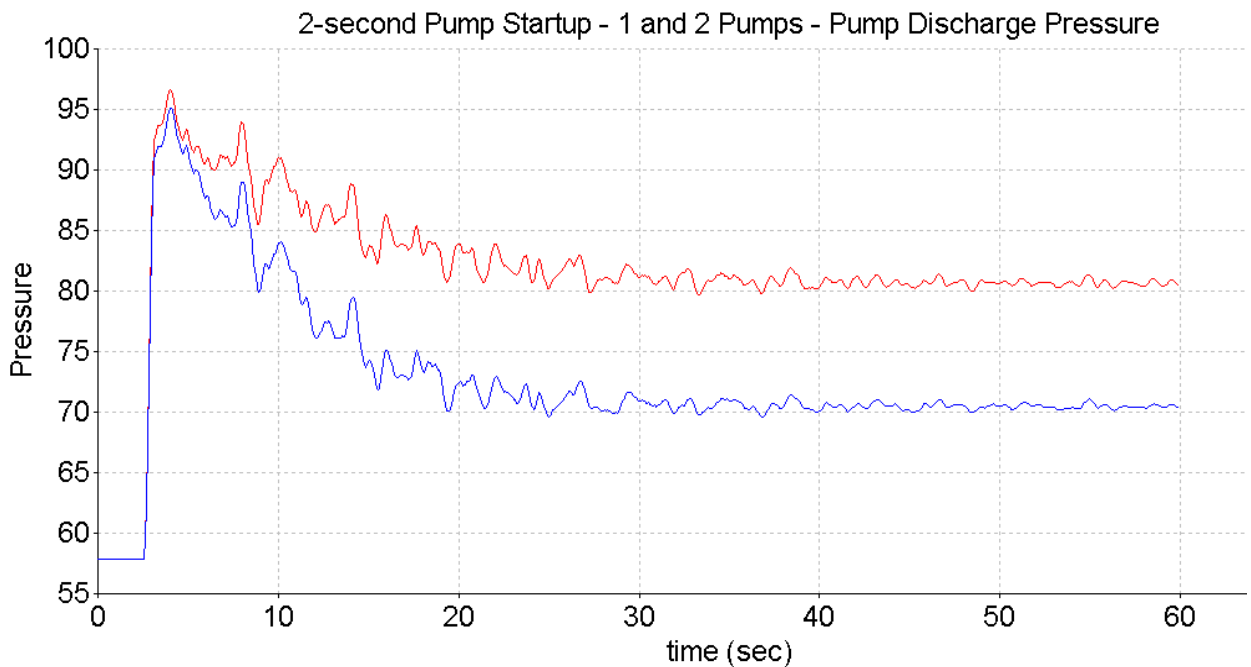


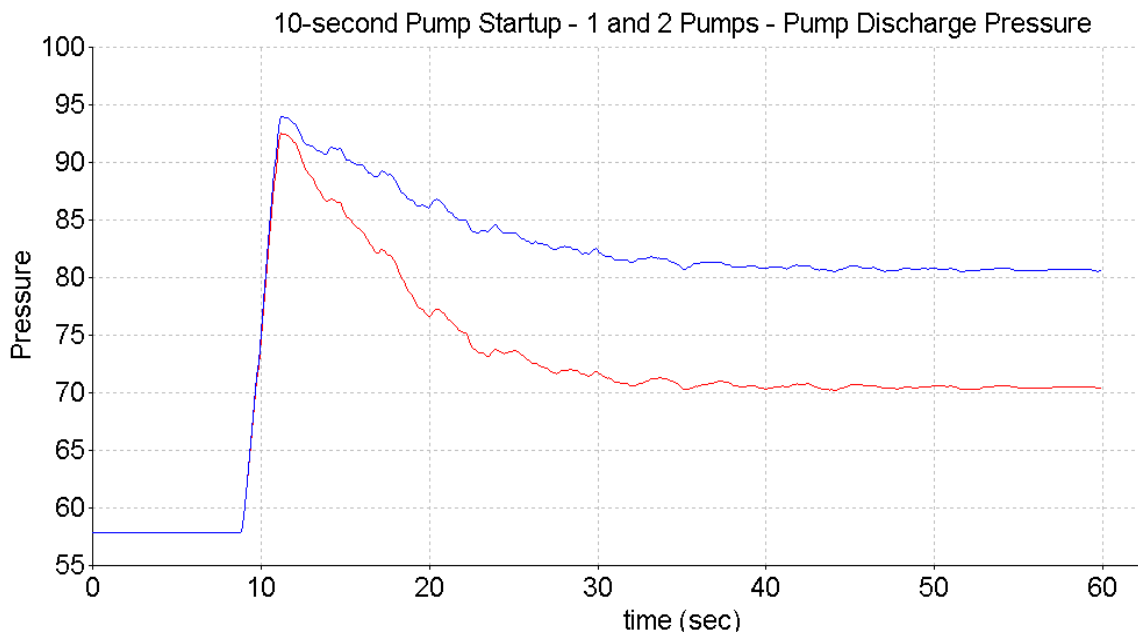
Figure 3-2 Results for Case 3-1

Several pump startup scenarios are set up as shown in Figure 3-1. Note that a pump which is initially off should be designated as such by clicking on the off button (top of the Node Information window in Classic or On/Off row in KYnetic). This will result in a red X imposed on the pump symbol on the map. Either pump description (pump

table or file) can be used. Also the Surge feature for handling multiple pumps is illustrated by running two simulations:

- a) startup a single pump,
- b) startup 2 parallel pumps.

Results are shown in Figures 3-2 and 3-3 for a 2-second and a 10-second (soft start) startup. A point of interest is that the pressure surge is not greatly affected by this difference in start time. This is because the pump must reach around 85% of full speed before the check valve can open and create a pressure spike. All the transient action occurs in the short period after the cv opens.



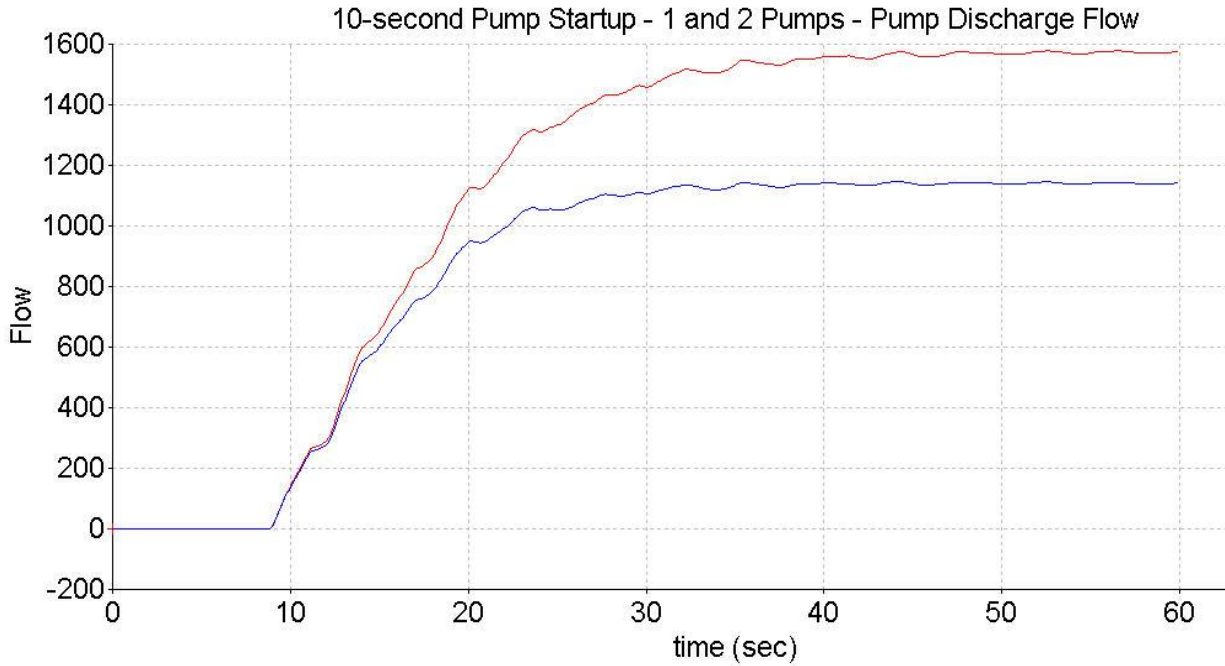


Figure 3-3 Results for Case 3-2

4 Fixed and Modulating Regulating Valves (*Regulator.P2K*)

(see also Training Exercise #1)

4-1 No modulation (Regulating Valve)

4-2 Modulation using Tool and Active Valve

REGULATING VALVE REPORT						
VALVE	VALVE	VALVE	VALVE	UPSTREAM	DOWNSTREAM	THROUGH
		(psi or gpm)		(psi)	(psi)	(gpm)
RV-1	PSV	40.00	ACTIVATED	40.00	4.05	425.56

REGULATING VALVE REPORT						
VALVE	VALVE	VALVE	VALVE	UPSTREAM	DOWNSTREAM	THROUGH
		(psi or gpm)		(psi)	(psi)	(gpm)
RV-1	PSV	40.00	ACTIVATED	40.00	7.14	578.09

Figure 4-1 Initial and Final Steady State Results for Regulator

Surge treats modeled regulating valves (PRVs, PSVs, and FCVs) as constant resistance valves and computes the resistance based on the initial conditions. This approach is based on the concept that for fast transient events, the regulating valves may be unable to respond. Figure 4-1 shows the Regulating Valve Report for two steady state scenarios with a PSV set at 40 psi. For the upper one no pumps are operating and for the lower one two pumps in parallel are operating.

Pipe2000 - Modulating Valve Settings (Copyright: KYPIPE LLC 2004)

Units
 English SI Head Pressure

Sp. Gravity = Flowrate

Wide Open Resistance
 Flow Coefficient

Initial Steady State Conditions
 Upstream Pressure psi
 Downstream Pressure psi
 Flowrate

Final Steady State Conditions
 Upstream Pressure psi
 Downstream Pressure psi
 Flowrate

Resistance = Headloss / {Flow²},
 where Headloss is in feet or meters
 and Flow is in cubic feet per second
 or cubic meters per second

Flow Coefficient = Flow (in gpm or
 m³/hr) that develops a pressure
 drop of 1 psi or 1 bar across the valve

Modulation Settings
 Wide-open Resistance
 Initial Ratio
 Final Ratio

Figure 4-2 Tool for Modulating Valve Calculations

Name AV-3

Active Valve

Elevation 630

Cv 100% 1000

Init Ratio 0.07

Valve Type

Cv Ratio

Node Type	Active Valve
Name	AV-3
Elevation	630
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0
Bypass Resistance	0
Grade	
Direction	←
On/Off	✓
Cv	1000
Initial Ratio	0.07
Valve Type	Cv Ratio

Active Valve Input Data

Node Changes

Cut Copy Paste Clear

Time/Case	Value
0 r	.07
10 r	.07
20 r	.1

Changes for AV-1		
Time	Change	Value
0	ratio	0.07
10	ratio	0.07
29	ratio	0.1

Active Valve Change Data

Figure 4-3 Active Valve Setup for Modulating Valve

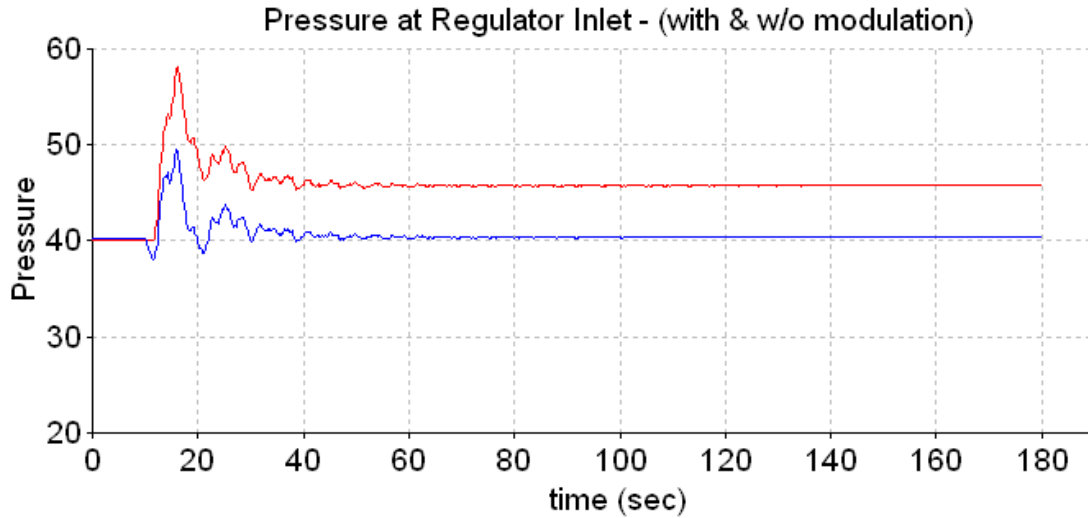
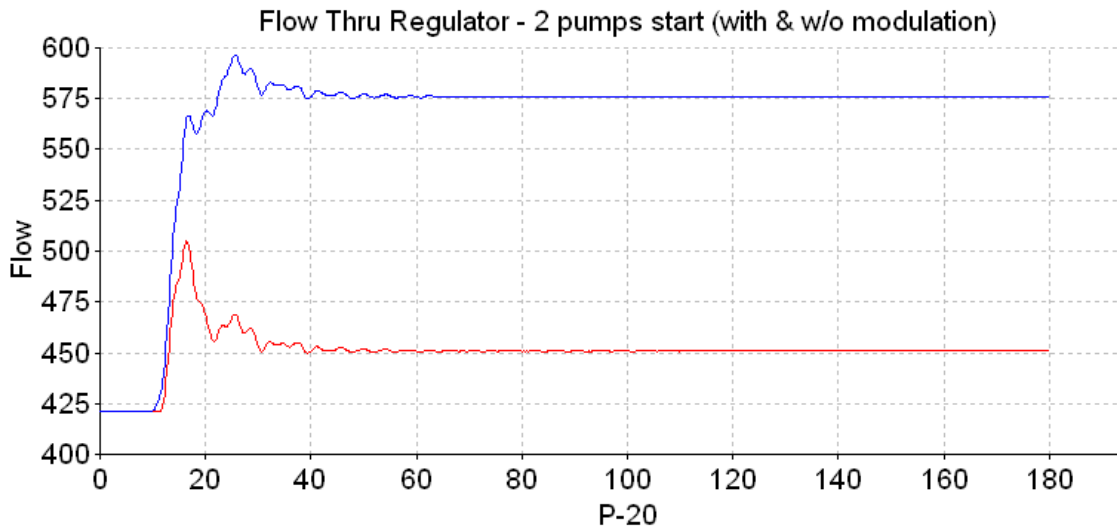


Figure 4-4 Results for Case 4-1

Case 4-1 illustrates the transient response to a two-pump startup using the Surge default approach. The resistance is based on the initial pressure drop (35.95 psi) at the initial flow (425.56 gpm) as shown in Figure 4-1. Case 4-2 illustrates the same transient using a Modulating Active Valve. Figure 4-2 illustrates the use of the Surge Modulating Valve Settings tool. The data shown on the screen was obtained from the steady state results depicted in Figure 4-1. The settings for the Modulating Active Valve are shown in Figure 4-3.

Figures 4-4 and 4-5 show results for the two methods of handling regulating valves. As shown, the responses are significantly different and it is important for a user to choose the most appropriate method for their application.



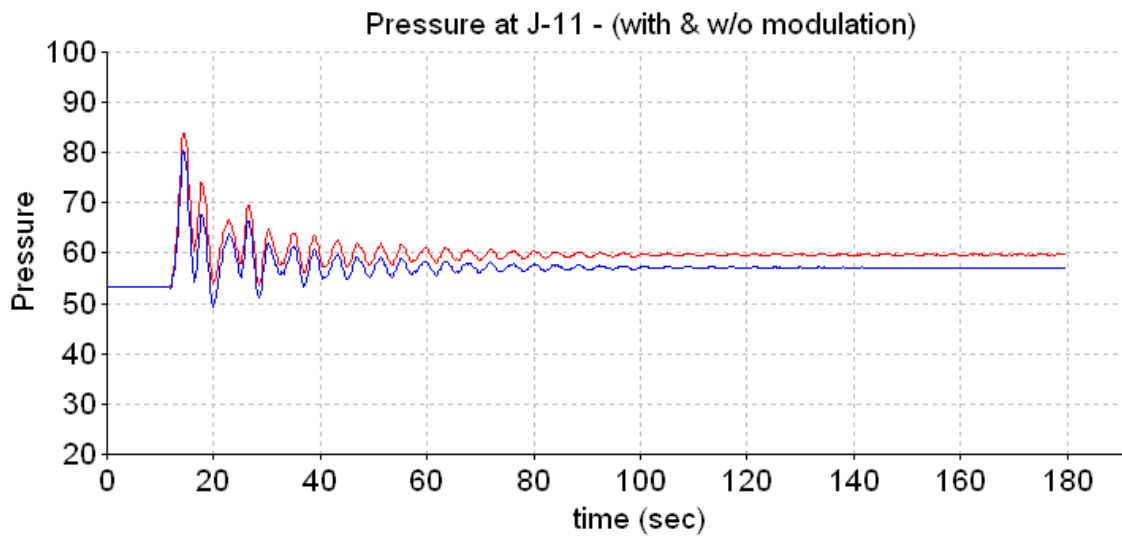


Figure 4-5 Results for Case 4-2

5 Compressor and Bladder Closed Surge Tanks (*Bladder Tank.P2K*)

5-1 Compressor surge tank – 40 cubic feet initial air

5-2 Compressor surge tank – compare 30 and 40 cubic feet

5-3 Bladder tank – precharge and sizing tool – 40 cubic feet initial air

A compressor surge tank is positioned downstream from the pump station as shown in Figure 1. This element has been disabled for the previous cases as shown in Figure 5-2. Surge provides an on/off button for this purpose and displays a red X when off. For Case 5-1 the surge tank is activated as a shown in Figure 5-3. For this example the tank is connected to the 12-inch line with a 6-inch pipe. The resistance of the connection is computed using the Resistance Calculation tool as shown in Figure 5-1. For a compressor type surge tank, the most significant parameter affecting the response is the initial volume of air which is maintained under the initial steady state pressure. The Tank Volume has no affect on the calculations but needs to be somewhat greater (~20%) than the maximum air volume which occurs during transient operations. The Exp(ansion) constant will be between 1.0 (isothermal) and 1.4 (adiabatic) and a value of 1.2 is recommended if the expansion process is not known.

Unit: English

Calculate Resistance From: Connection to Tank

No. of elbows: 2

Pipe Diameter: 6 in

Length of Pipe: 6 ft

Additional k's: 1.5

Compute Resistance

Resistance = 1.30

Formula Close

Tank Resistance Tool

Name: SDO-1

Closed Srg Tnk

Elevation: 610

Inflow R: 1.3

Outflow R: 1.3

Device Data

Tank Vol: 120

In Gas Vol: 40

Exp Con: 1.2

Hybrid Tank

Node Type	Vert Closed Surge
Name	SDO-1
Elevation	610
Title	
On/Off	✔
Inflow Resistance	1.3
Outflow Resistance	1.3
Tank Volume	120
Initial Gas Volume	40
Expansion Constant	1.2
Diameter	4
Initial Level	4
Hybrid	<input type="checkbox"/>
Elevation Difference	0

Compressor Tank Data

Figure 5-1 Tool and Data Screens for Case 5

Del More Data Chng

Off Less Rslt User

Name: SDO-1

Closed Srg Tnk

Elevation: 610

Inflow R: 1.3

Outflow R: 1.3

Node Type	Vert Closed Sur
Name	SDO-1
Elevation	610
Title	
On/Off	⊘
Inflow Resistance	1.3
Outflow Resistance	1.3
Tank Volume	120

Figure 5-2 Surge Tank Location turned Off

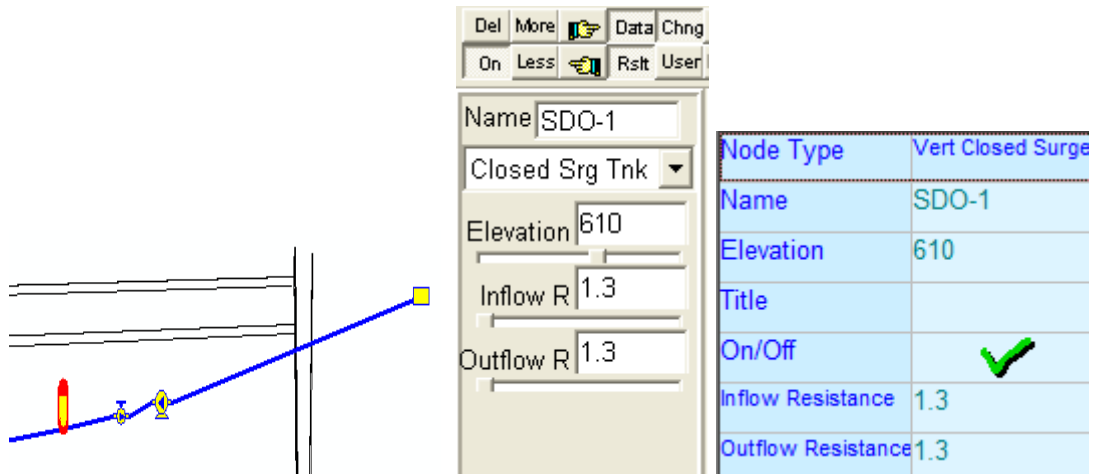


Figure 5-3 Surge Tank Location turned On

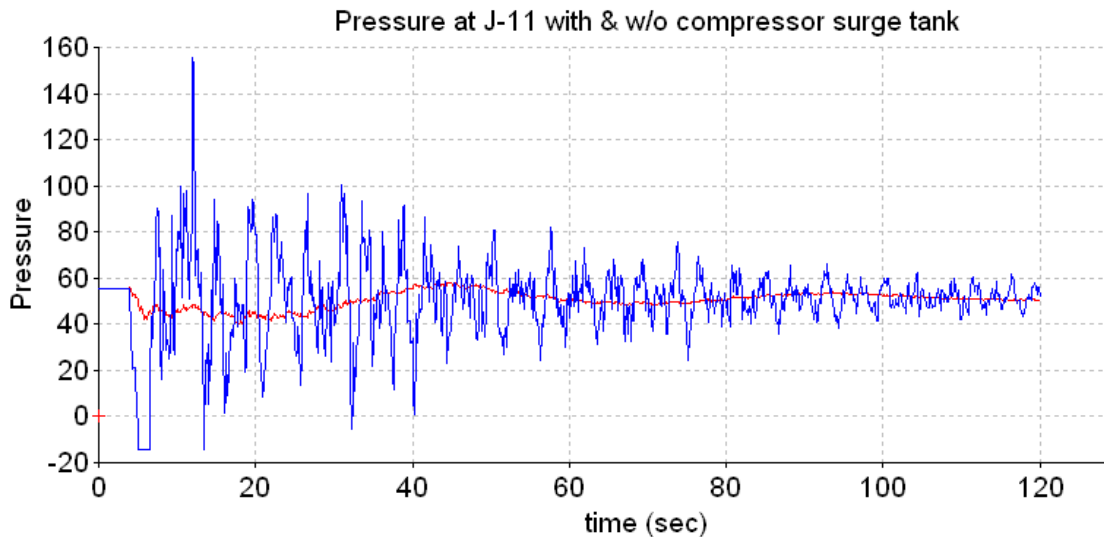


Figure 5-4 Results for Case 5-1

Figure 5-4 shows the pressure history at J-11 with and without the compressor tank following a pump trip. This shows that the surge tank provides very good protection.

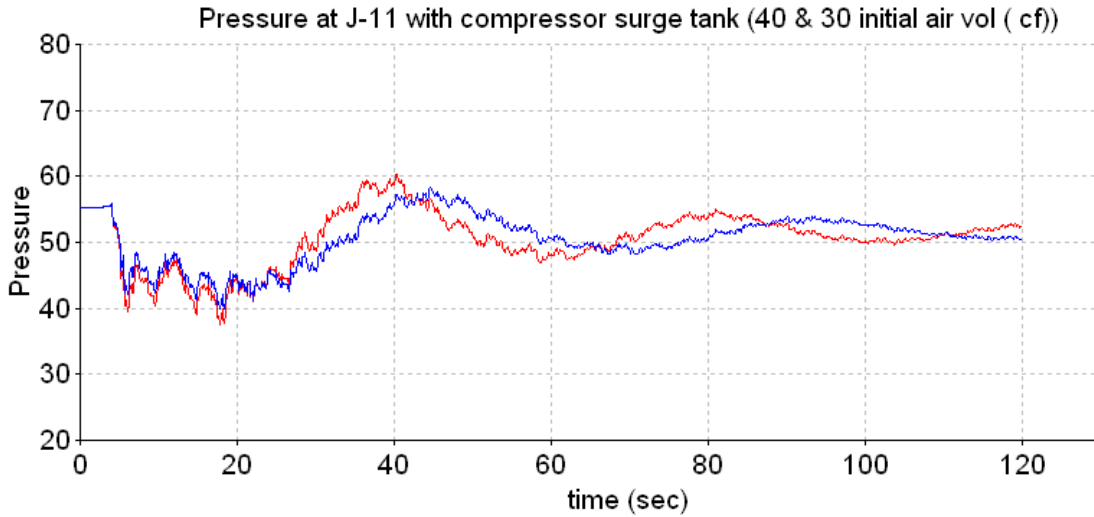


Figure 5-5 Results for Case 5-2

Figure 5-5 shows also the response with a smaller initial air volume (30 ft³). This shows that the smaller air volume results in larger pressure transients and a higher perturbation frequency.

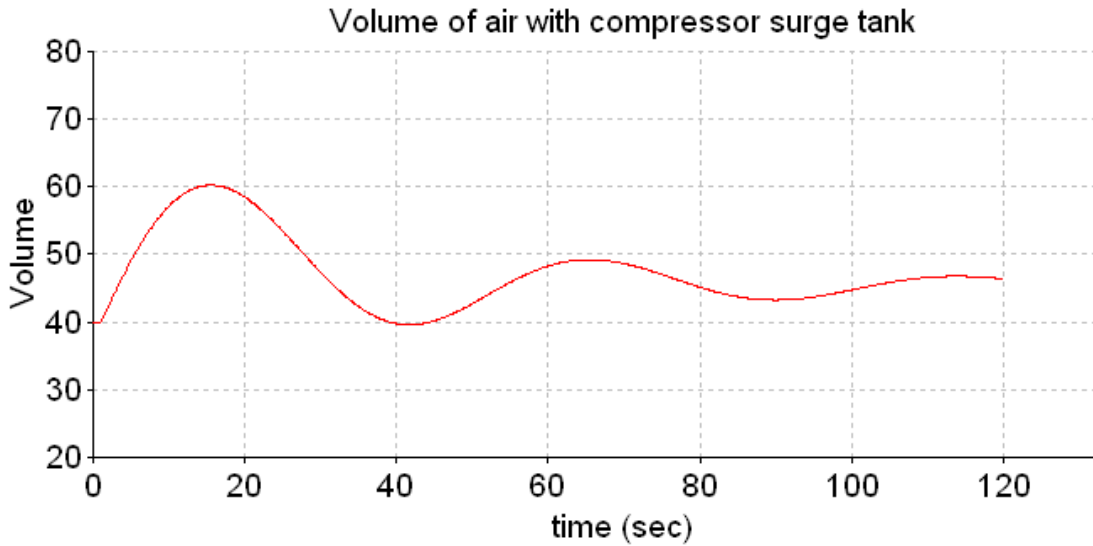


Figure 5-6 Results for Case 5-2 (to size Bladder Tank)

Figure 5-6 shows the variation in the volume of air during the transient. This information is required to size the surge tank (to contain the air with a safety factor) and also to calculate parameters for a Bladder Surge Tank which will provide the same protection. Because of the requirement to define the precharge pressure for a bladder tank it is recommended that the surge analysis be initially carried out using a compressor

tank and varying the initial volume of air until an acceptable result is obtained. Then the Bladder Precharge tool can be used as shown in Figure 5-7 to calculate the required tank volume and precharge pressure (head). Data for the Bladder Tank can then be entered as shown in Figure 5-8.

Pipe2000 - Bladder Tank (CopyRight: KYPIPE LLC 2004)

Units

English SI

Volume

Gallons Cubic Feet

Pressure

PSI Feet

P(atm) = 33.92 ft or 14.7 psi
P(atm) = 10.34m or 101.435kPa

Maximum Air Volume
Initial Air Pressure
Initial Air Volume

Precharge Pressure
Bladder Volume

Figure 5-7 Bladder Precharge Tool Case 5-3

Name	SDO-2	Device Data	
	Bladder Tank		
Elevation	610	Tank Vol	72
Inflow R	1.3	Exp Con	1.2
Outflow R	1.3	Preset Hd	73
		<input type="checkbox"/> Use Pressure	

Node Type	Vert Bladder Tank
Name	SDO-2
Elevation	610
Title	
On/Off	<input checked="" type="checkbox"/>
Diameter	4
Inflow Resistance	1.3
Outflow Resistance	1.3
Expansion Constant	1.2
Initial Level	4
Tank Volume	72
Preset Head	73
Elevation Difference	0

Figure 5-8 Bladder Tank Data Screen Case 5-3



Figure 5-9 Results for Case 5-1 and Case 5-3

Figure 5-9 shows the results for a compressor tank with an initial air volume of 40 ft³ (case 5-1) and an equivalent bladder tank (case 5-3). As shown, the solutions are virtually identical.

6 Valve Closures (*Altitude Valve.P2K*)

6-1 2-second closure

6-2 20-second closure

Cases 6-1 and 6-2 illustrate transients due to a valve closure. A 2- and 20-second closure of the altitude valve for Tank 1 are simulated. Figure 6-1 shows the data screen for the valve and the Change Data to produce the valve closure. The valve is a gate valve.

Figure 6-2 shows the results for both the 2-second (case 6-1) and the 20-second (case 6-2) closures and, as expected, the more rapid closure produces the larger pressure surge. For this case the pressure surge exceeds 200 psi which could be excessive.

Name AV-2

Active Valve


Elevation 630



Cv 100% 500

Init Ratio 1

Valve Type

Gate



Node Type	Active Valve
Name	AV-2
Elevation	630
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0.1
Bypass Resistance	0
Grade	----
Direction	
On/Off	
Cv	500
Initial Ratio	1
Valve Type	Gate

Gate Valve Data

Node Changes

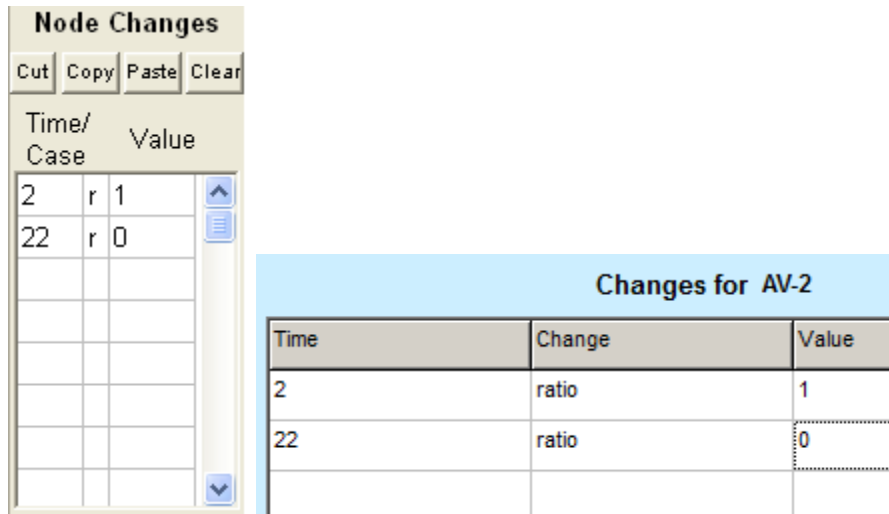
Cut Copy Paste Clear

Time/ Case	Value
2	r 1
4	r 0

Changes for AV-2

Time	Change	Value
2	ratio	1
4	ratio	0

2-Second Valve Closure



20-Second Valve Closure

Figure 6-1 Data Screens for Altitude Valve and 2- and 20-second Closures

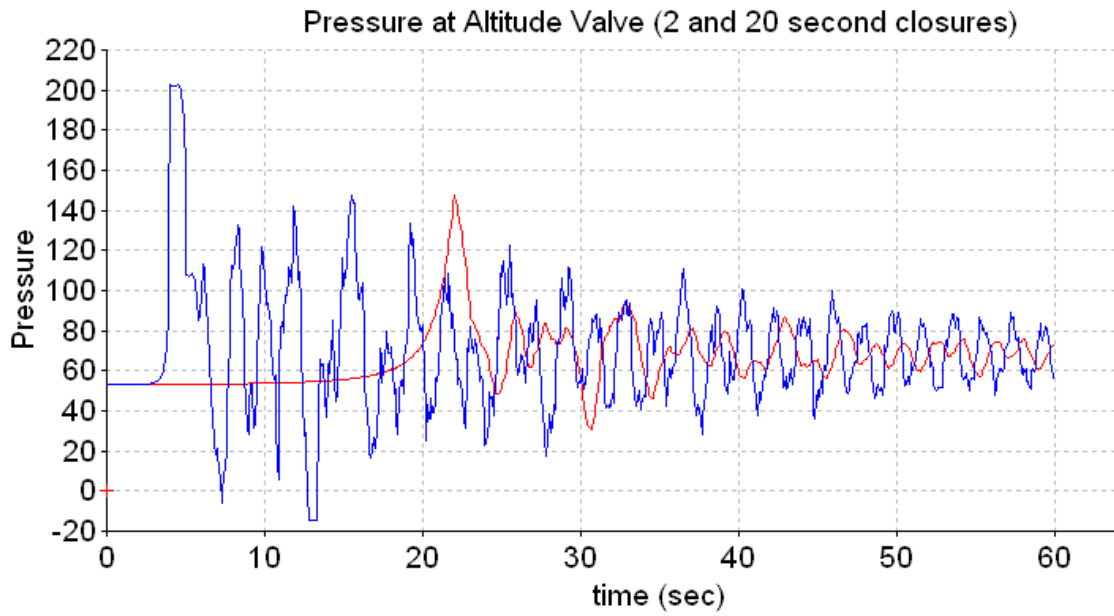


Figure 6-2 Results for Case 6-1 and Case 6-2

7 Relief Valve to Control Pressure Surge Due to Valve Closure (*Pressure Relief Valve.P2K*)

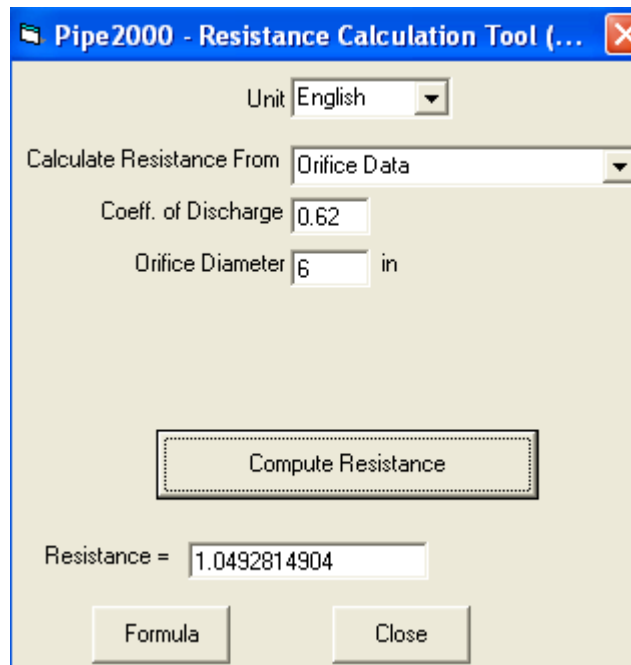
7-1 Add relief valve and provide data



Figure 7-1 Location of Altitude Valve Relief Valve

A 6-inch relief valve was inserted a short distance downstream from the Tank 1 altitude valve as shown above (Figure 7-1). The wide-open resistance of the valve was computed using the Resistance Tool and considering the resistance for a 6-inch orifice. This is illustrated in Figure 7-2 along with the input data for the relief valve. The opening pressure, opening time, closing pressure and closing time were chosen based on the expected steady conditions with the altitude valve open and closed. The External Head is input as zero indicating that the relief valve vents to the atmosphere.

Figure 7-3 shows pressure histories at the altitude valve and at J-11 with and without the Relief Valve in service.

A screenshot of a software dialog box titled "Pipe2000 - Resistance Calculation Tool (...)". The dialog has a blue title bar with a close button. The main area is light beige. At the top, there is a "Unit" dropdown menu set to "English". Below that is a "Calculate Resistance From" dropdown menu set to "Orifice Data". Underneath are two input fields: "Coeff. of Discharge" with the value "0.62" and "Orifice Diameter" with the value "6" and the unit "in". A large button labeled "Compute Resistance" is centered below these fields. At the bottom, there is a text field showing "Resistance = 1.0492814904". Below this field are two buttons: "Formula" and "Close".

Resistance Calculation Tool

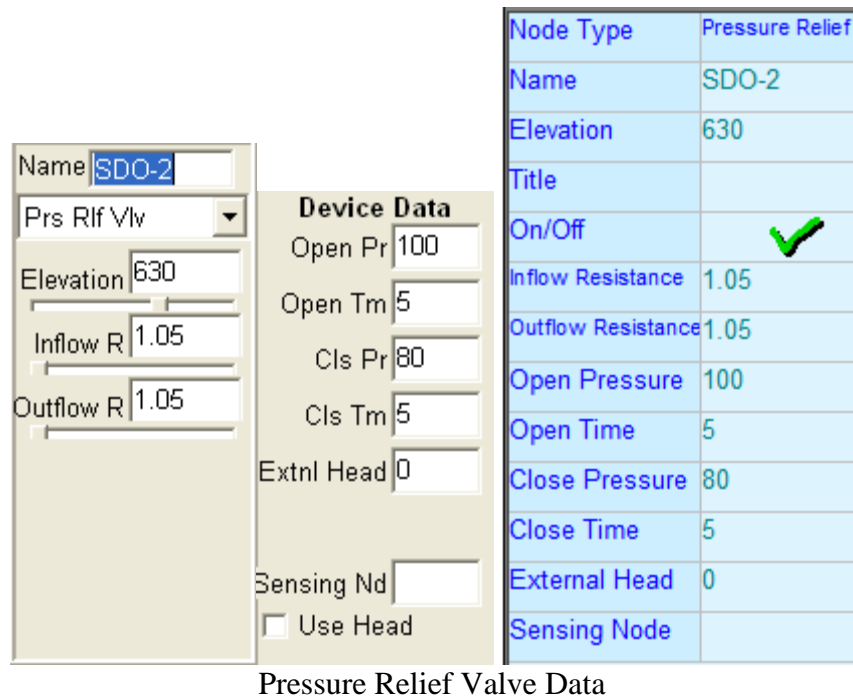
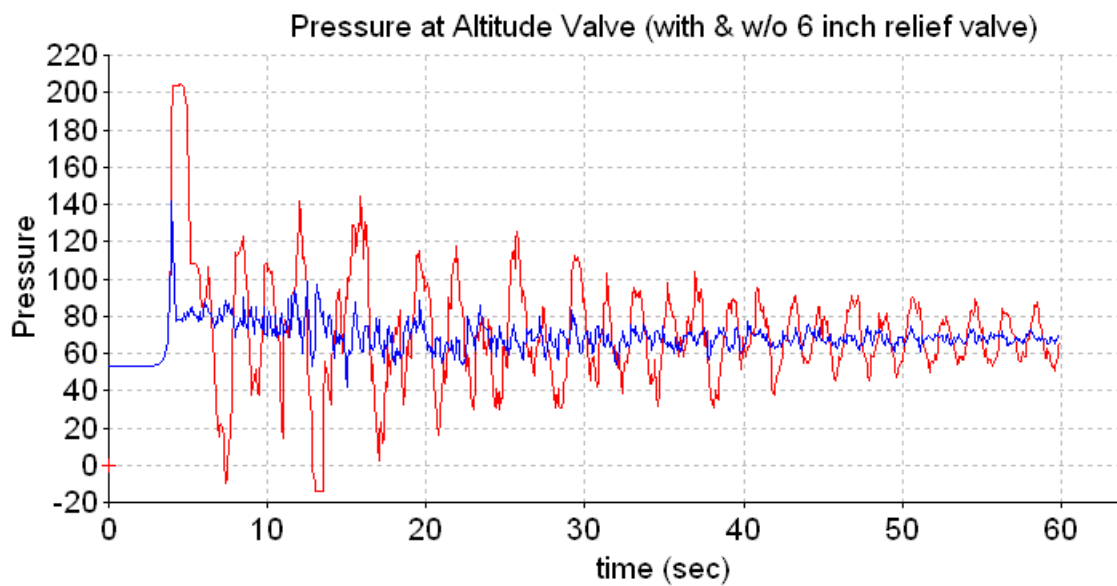


Figure 7-2 Resistance Tool for 6-inch Relief Valve Resistance and Data Screens



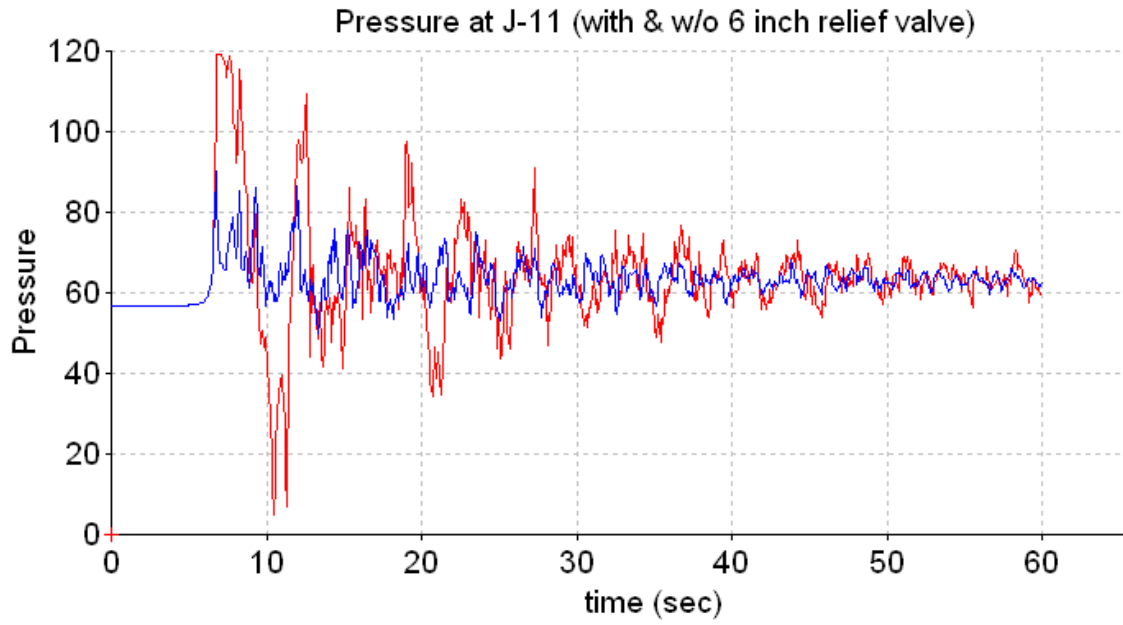


Figure 7-3 Results for Case 7-1

8 Hydrant Operations (Startup and Shut Down) (*Hydrant Open.P2K*)

8-1 Hydrant opens in 2- and 10-seconds

8-2 Hydrant closes in 2- and 10-seconds

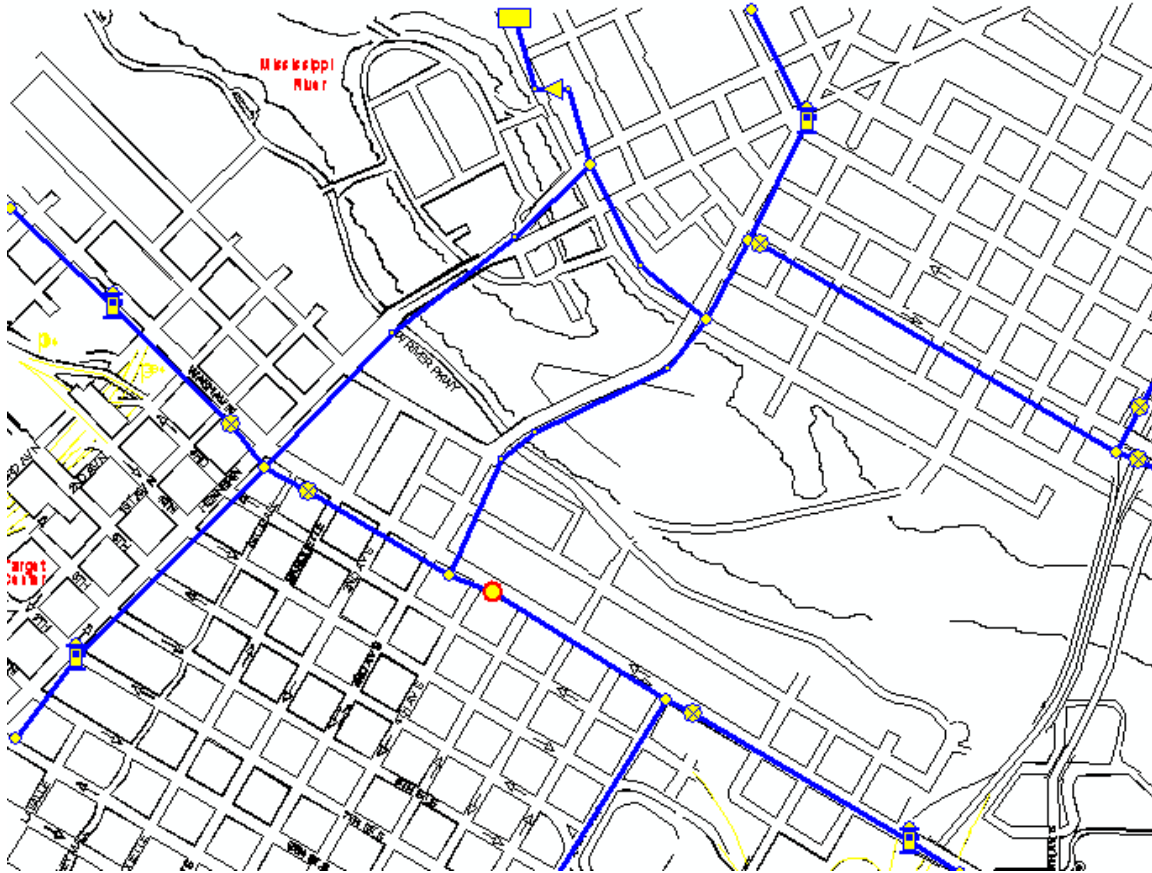


Figure 8-1 Location for Fire Hydrant

Figure 8-1 shows the location of a fire hydrant which is changed to a junction to analyze hydrant startup and shutdown scenarios. A steady state analysis is conducted to show that a fire flow in excess of 1850 gpm could be pumped from that location and still maintain a residual pressure of 20 psi throughout the system. However, the steady state analysis does not address the transient low pressures which can develop during startup and high pressures due to shutdown. In order to illustrate this, 2-second and 10-second startup and shutdown scenarios were modeled for a fire flow of 1800 gpm. The data screens for the startup are shown in Figure 8-2 and the results for the pressure at J-11 are shown in Figure 8-3. The corresponding information is shown in Figures 8-4 and 8-5 for the shutdown.

This exercise effectively illustrates that while a system may be able to deliver a specified fire flow and maintain the required residual pressure, care must be taken during the startup and shutdown of the hydrant to avoid excessive high and low pressures.

The screenshot shows a software interface for configuring a junction. The 'Name' field is set to 'J-13'. The 'Junction' type is selected from a dropdown menu. The 'Elevation' is set to 611. The 'Demand' is set to 0. The 'Dm Type' is set to 1. To the right, a table displays the node's properties:

Node Type	Junction
Name	J-13
Elevation	611
Demand	0
Demand Type	1

Junction Data

The screenshot shows the 'Node Changes' window with a table of changes for junction J-13. The table has columns for 'Time/Case', 'Change', and 'Value'. The changes are as follows:

Time/Case	Change	Value
0	d	0
2	d	0
4	d	1800

Below this is a detailed view titled 'Changes for J-13' with the following table:

Time	Change	Value
0	demand	0
2	demand	0
4	demand	1800

2-Second Hydrant Open

Node Changes	
Time/Case	Value
0	d 0
2	d 0
12	d 1800

Changes for J-13		
Time	Change	Value
0	demand	0
2	demand	0
12	demand	1800

10-Second Hydrant Open

Figure 8-2 2-second and 10-second Hydrant Startup

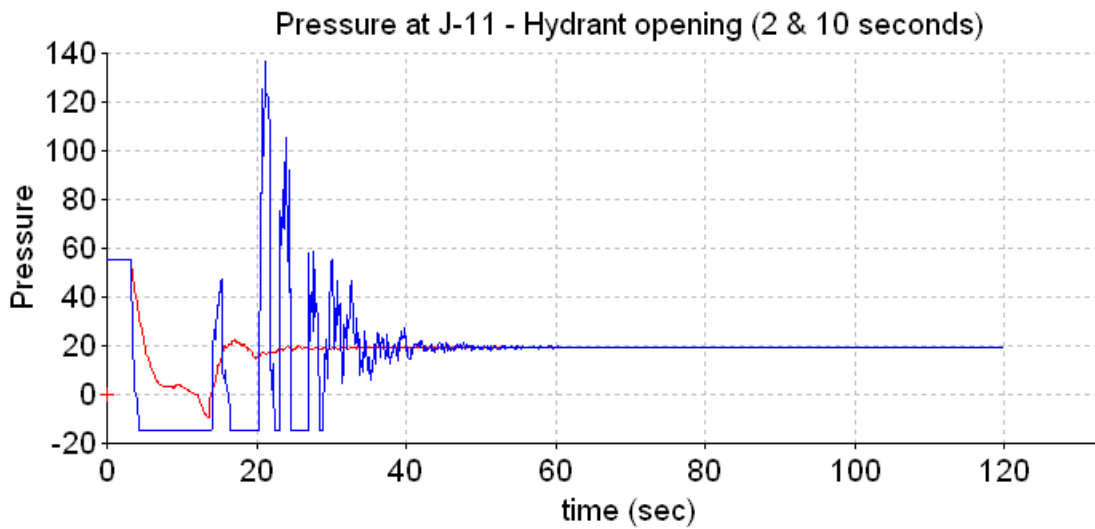


Figure 8-3 Results for Case 8-1

Name J-13

Junction

Elevation 611

Demand 1800

Dm Type 1

Node Type	Junction Single Dem
Name	J-13
Elevation	611
Demand	1800
Demand Type	1
Title	
Ignore Changes	<input type="checkbox"/>

Junction Data with Initial Demand

Node Changes

Cut Copy Paste Clear

Time/ Case		Value
0	d	1800
2	d	1800
4	d	0

Changes for J-13		
Time	Change	Value
0	demand	1800
2	demand	1800
4	demand	0

2-Second Hydrant Closure

Node Changes

Cut Copy Paste Clear

Time/ Case		Value
0	d	1800
2	d	1800
12	d	0

Changes for J-13		
Time	Change	Value
0	demand	1800
2	demand	1800
12	demand	0

10-Second Hydrant Closure

Figure 8-4 2-second and 10-second Hydrant Shutdown

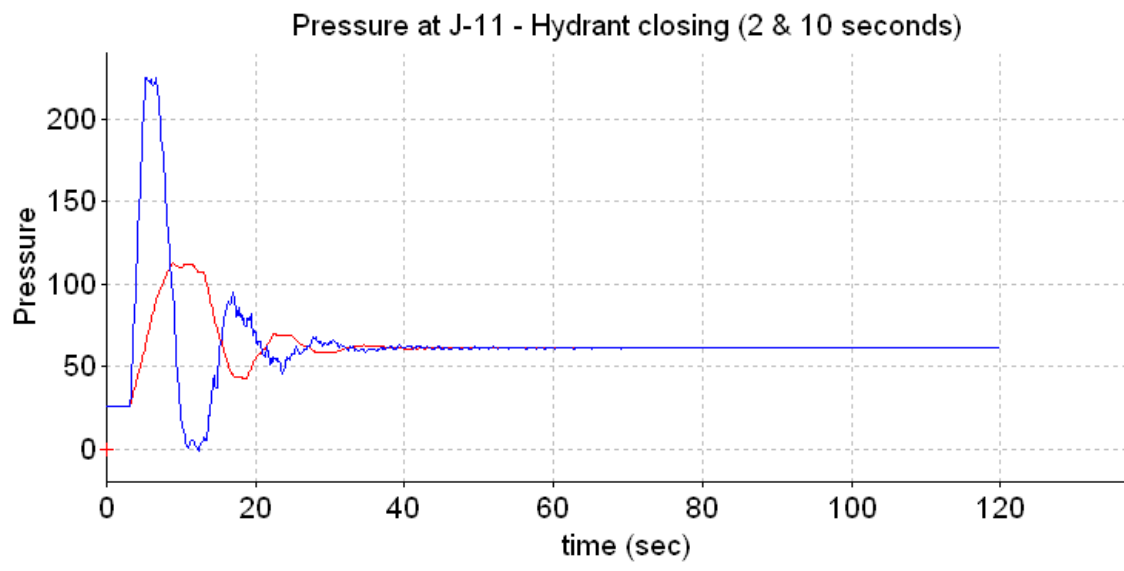


Figure 8-5 Results for Case 8-2

9 Simulated Line Break Using Rupture Disk (*Rupture Disk.P2K*)

9-1 Fixed demands

9-2 Pressure sensitive demands

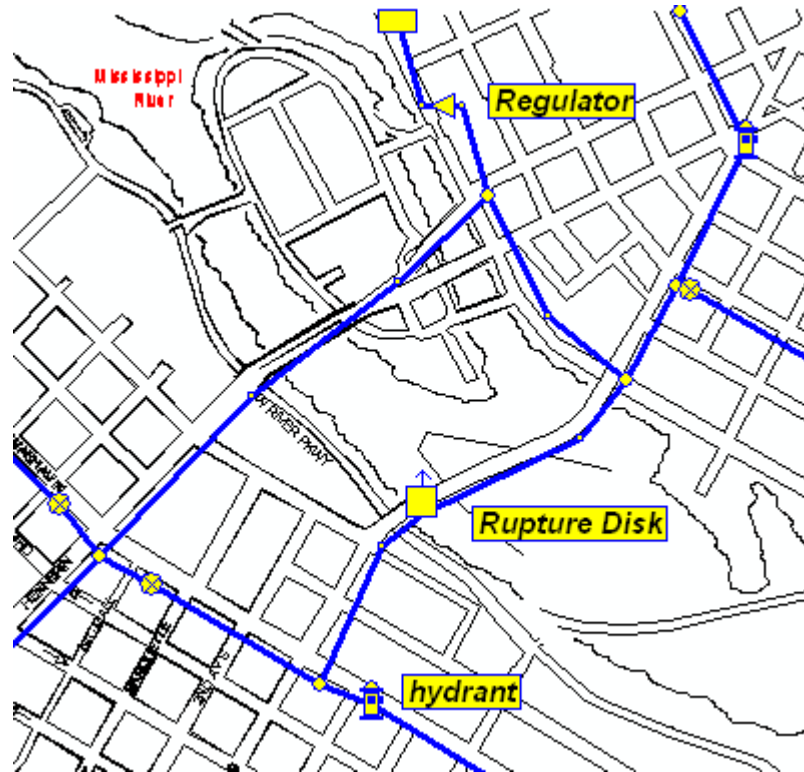


Figure 9-1 Location of Rupture Disk to simulate Line Break

Surge features a very useful surge control which can be used to simulate a line break. A rupture disk with a pressure setting below the initial pressure at the rupture disk will activate at the start of a transient simulation. This will simulate a system operating at steady state which suddenly experiences a catastrophic break which results in flow exiting the system through the opening. The only data required is the resistance of the opening through which the water exits the system.

Figure 9-1 shows the location of a rupture disk inserted in an 8-inch main to simulate the line break. The Resistance tool is used to calculate the resistance through an 8-inch circular opening exiting to atmosphere. An activating (opening) pressure of 20 psi which is well below steady state pressure is input as shown in Figure 9-2.

Results for the pressure at J-11 are shown in Figure 9-3 using the Fixed Demand option (

100
3.74
0.35

 or System Data | Simulation Specs). Since it is highly unlikely that the initial demands can be maintained, a second scenario is carried out using Pressure Sensitive

Demands (Figure 9-4). Although less severe, this transient produces cavitation and low pressure throughout the distribution system.

Resistance Calculator Tool

Node Type	Rupture Disk (Prs)
Name	SDO-2
Elevation	590
Title	
On/Off	✓
Inflow Resistance	0.33
Outflow Resistance	0.33
Open Pressure	20

Rupture Disk Data

Figure 9-2 Resistance Tool – 8-inch Line Break and Rupture Disk Data Screens

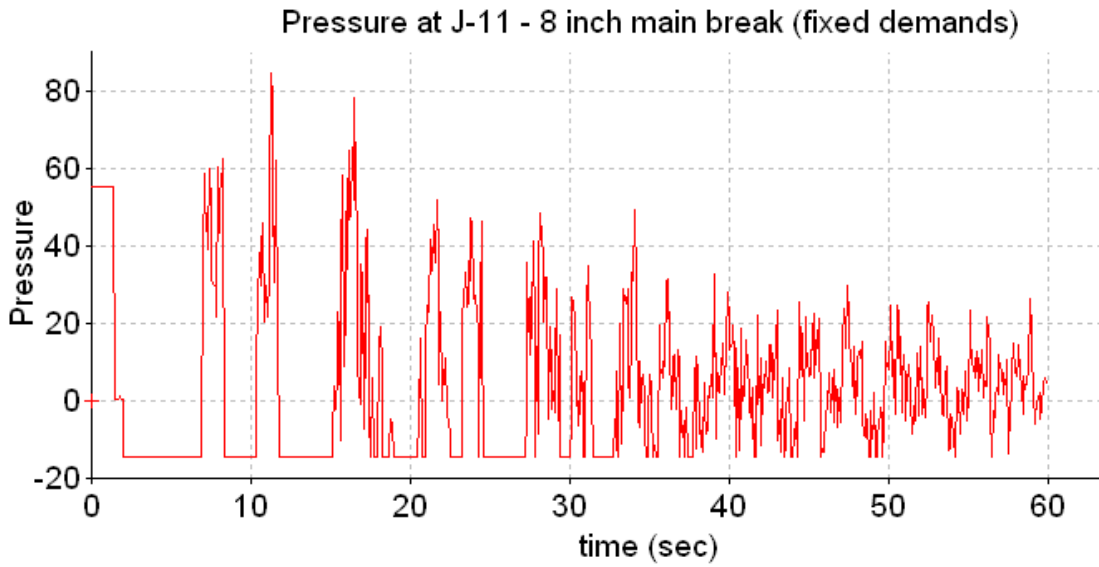


Figure 9-3 Results for Case 9-1

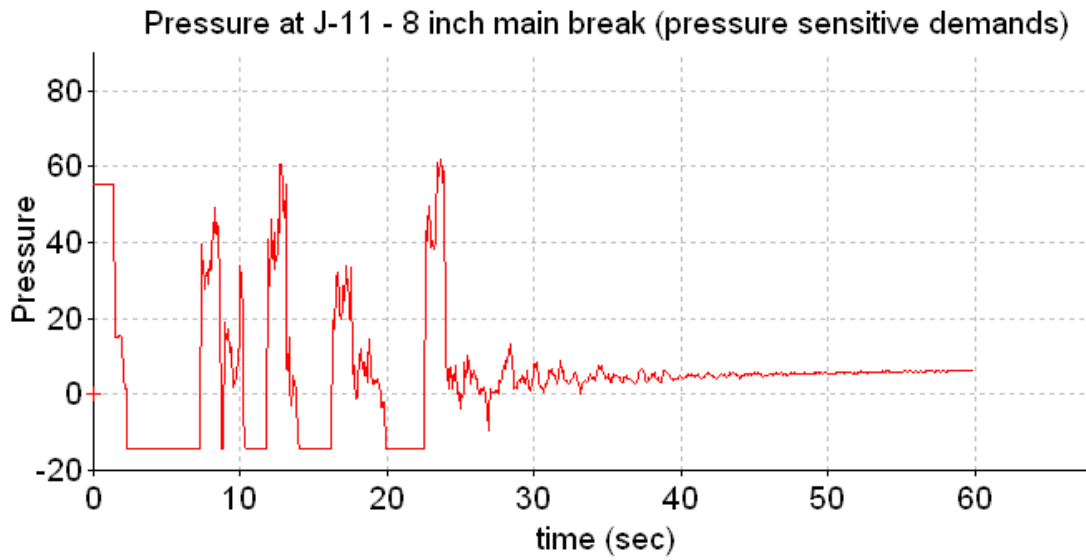


Figure 9-4 Results for Case 9-2

10 Simulated Pump Trip Using Inflow Node (Negative Demand.p2k)

An additional alternative for modeling a pump shutdown (including pump trip) is to model the pump as a junction Node with a negative demand which inputs the operating pump flow. This will result in a head at the node equal to the pump discharge head at the operating flow condition. Figure 10-1 shows the setup for modeling the same pump used for Cases 1 and 2 (1141 gpm @ 165 feet). Data screens are shown in Figure 10-2 for the Pump Node and a 3 second rampdown of the flow to simulate a pump trip. The results are shown in Figure 10-3.

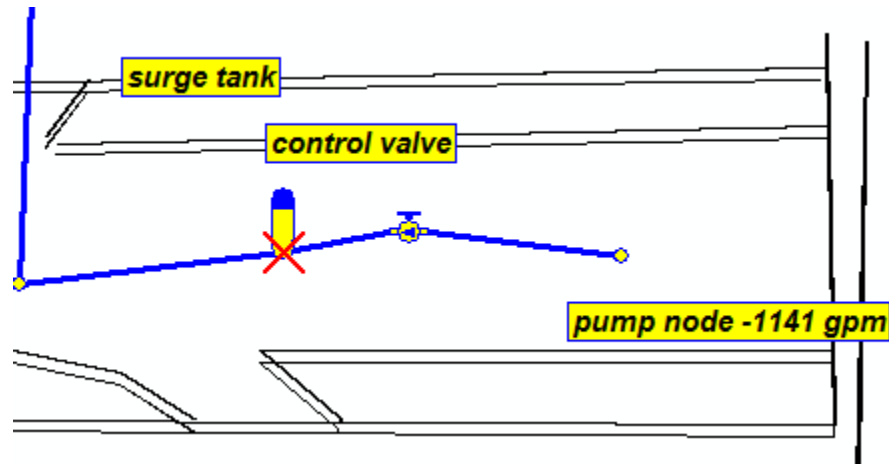


Figure 10-1 Modeling an Inflow (Pump) Node

Name J-13

Junction

Elevation 610

Demand -1141

Dm Type 1

Node Type	Junction Single
Name	J-13
Elevation	610
Demand	-1141
Demand Type	1
Title	
Ignore Changes	<input type="checkbox"/>

Junction Data with Inflow

Node Changes

Cut Copy Paste Clear

Time/Case	Value
2	d -1141
5	d 0

Changes for J-13		
Time	Change	Value
2	demand	-1141
5	demand	0

Rampdown of Junction Demand

Figure 10-2 Data Screens for Pump Junction Node 3-Second Rampdown

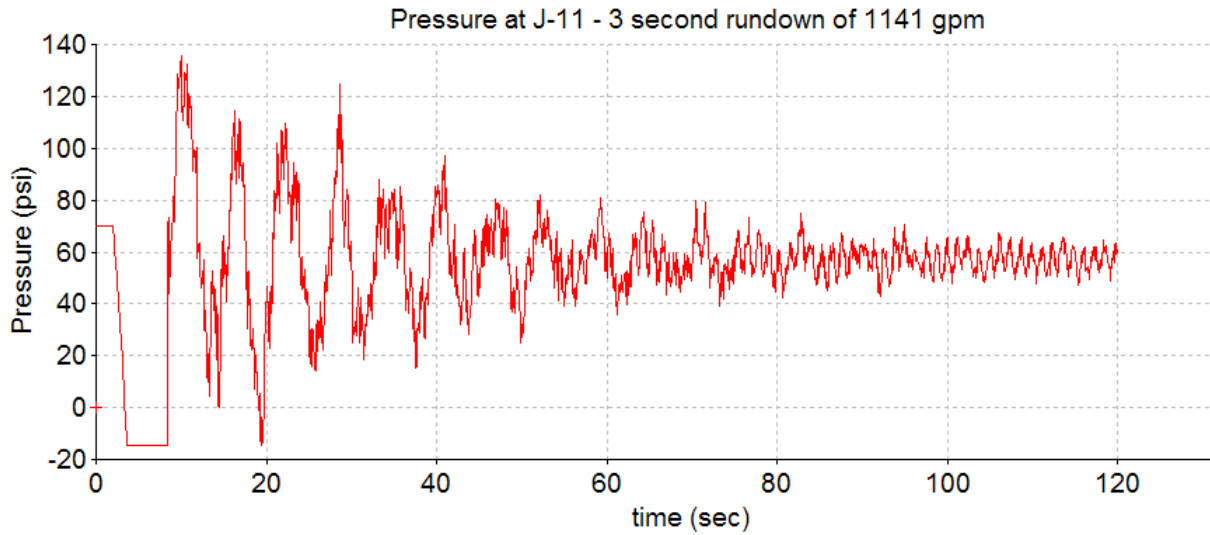


Figure 10-3 Results for Case 10

Figure 10-4 shows the results previously presented for simulating a pump trip by:

- 1) ramping down the pump speed from full (1) to zero in 2 seconds
- 2) using a pump file based on operating conditions and calling for a pump trip

All three approaches produce similar results. One advantage of using a Pump Junction Node is that details about the pump station are not required (check valve characteristics, etc). This approach also eliminates instabilities (excessive pressure spiking) due to check valve action and cavitation. It may also be argued that this is a relatively conservative approach because all flow provided by the pump is removed subjecting the pipeline to a maximum downsurge. However, this approach will not account for effects such as flow reversal through the pump due to check valve closing delays.

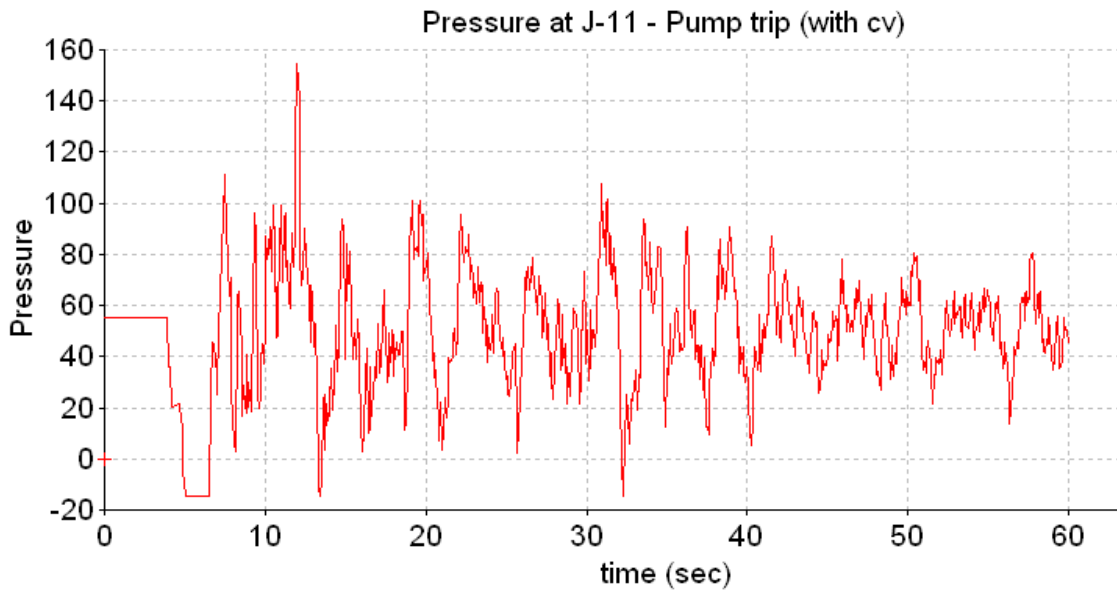
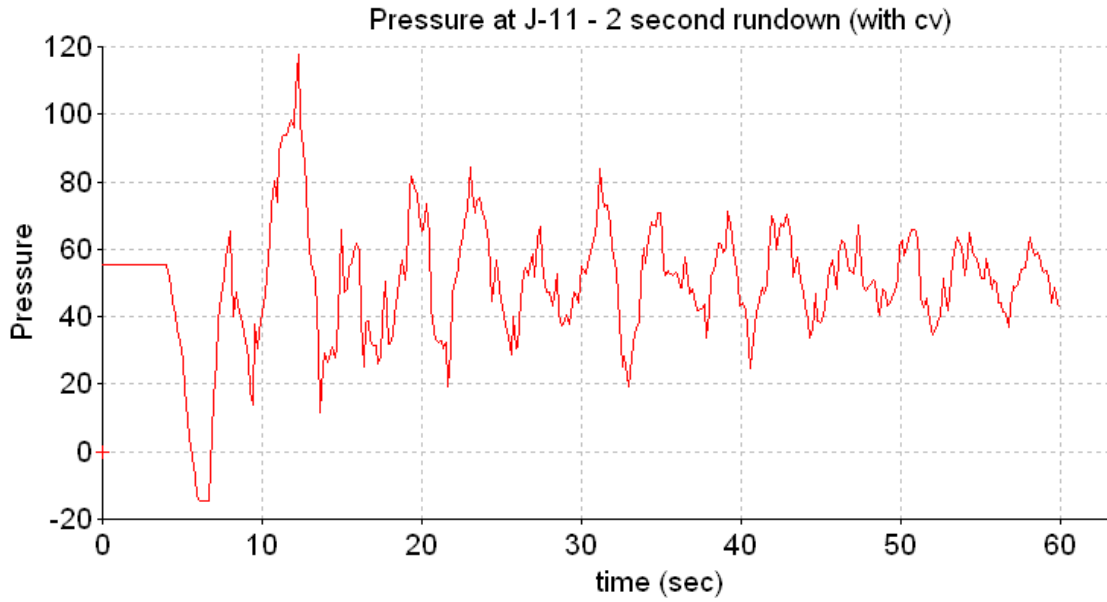


Figure 10-4 Comparing Results for Pump Trip Modeling (Cases 1 and 2)

Appendix 1-A Demo1 – Municipal Water Distribution System

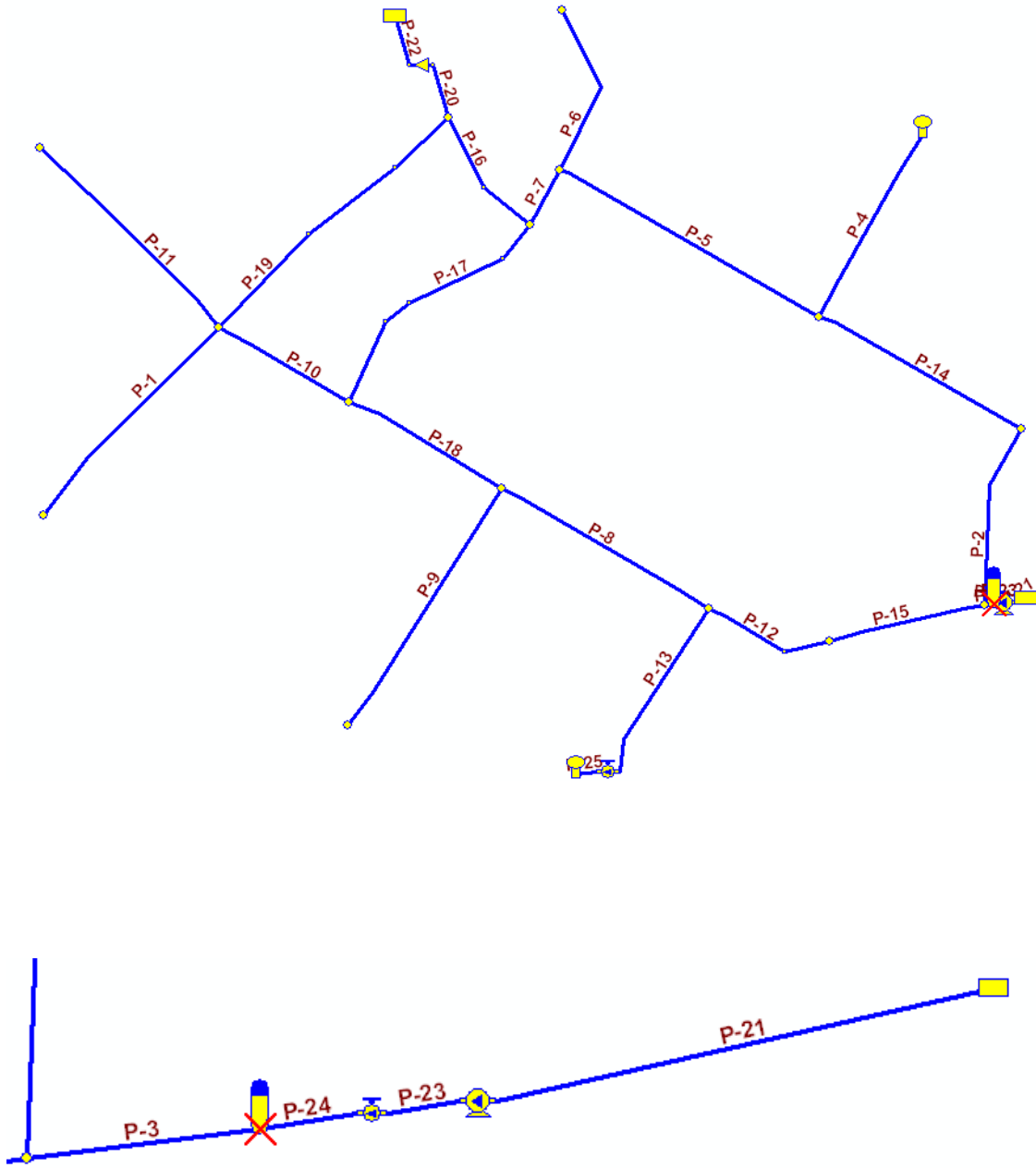


Figure I-1 Pipe Names

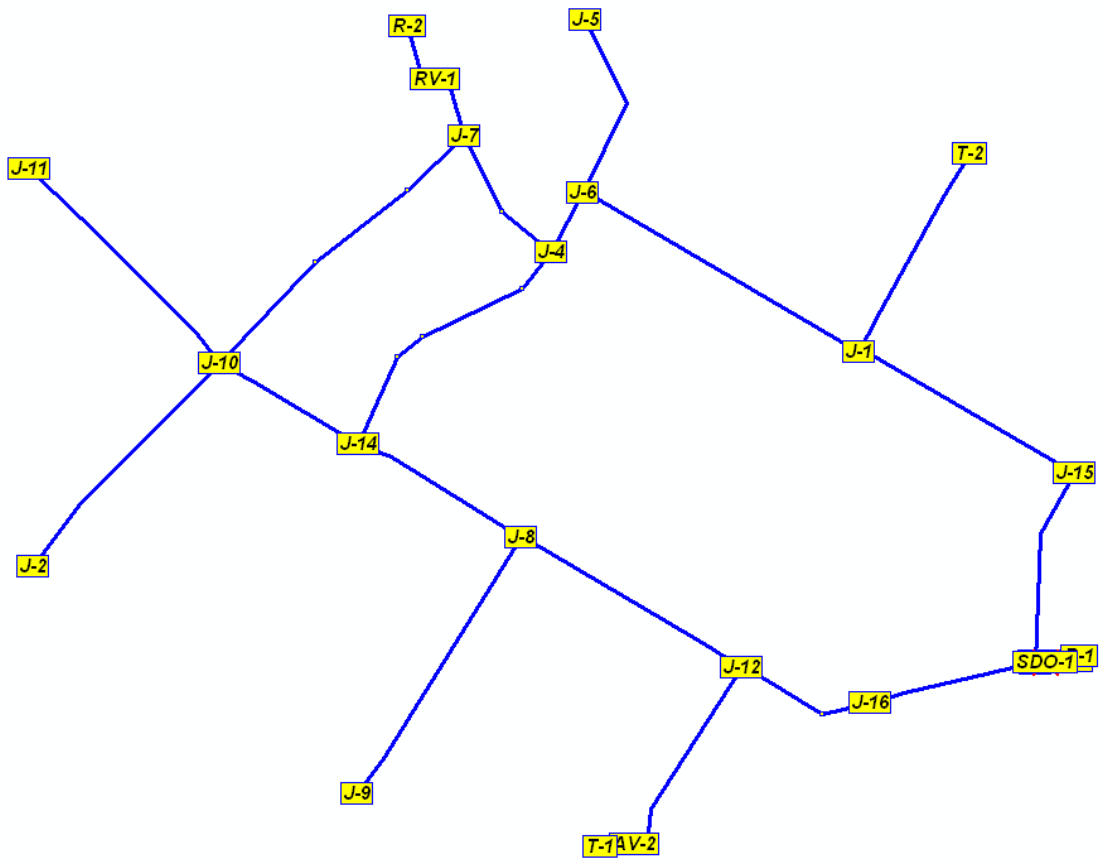


Figure I-2 Node Names

Demo1 - Pipe and Node Data

PIPE NAME	NODE NAMES		LENGTH (ft)	DIAMETER (in)	ROUGHNESS COEFF.	MINOR LOSS COEFF.
	#1	#2				
P-1	J-2	J-10	2844.00	6.00	130.0000	0.00
P-10	J-10	J-14	1649.00	8.00	140.0000	0.00
P-11	J-10	J-11	2801.00	6.00	130.0000	0.00
P-12	J-12	J-16	1464.00	8.00	140.0000	0.00
P-13	J-12	AV-2	2131.00	8.00	140.0000	3.40
P-14	J-15	J-1	2550.00	8.00	140.0000	0.00
P-15	J-16	J-3	1753.00	10.00	120.0000	0.00
P-16	J-4	J-7	1532.00	8.00	140.0000	0.00
P-17	J-4	J-14	2938.00	8.00	140.0000	0.00
P-18	J-14	J-8	1942.00	8.00	140.0000	0.00
P-19	J-7	J-10	3447.00	8.00	140.0000	0.00
P-2	J-3	J-15	2059.00	10.00	120.0000	0.00
P-20	J-7	RV-1	657.00	6.00	130.0000	0.00
P-21	Pump-1	R-1	250.00	12.00	120.0000	7.50
P-22	@~RV-1	R-2	613.00	6.00	130.0000	0.00
P-23	AV-1	@~Pump-1	50.00	12.00	120.0000	0.00
P-24	SDO-1	@~AV-1	50.00	12.00	120.0000	0.00
P-25	@~AV-2	T-1	355.00	8.00	140.0000	0.00
P-3	J-3	SDO-1	100.00	12.00	120.0000	6.40
P-4	J-1	T-2	2337.00	8.	140.0000	1.90
P-5	J-1	J-6	3296.00	8.00	140.0000	0.00
P-6	J-6	J-5	1983.00	6.00	130.0000	0.00
P-7	J-6	J-4	686.00	8.00	140.0000	0.00
P-8	J-8	J-12	2633.00	8.00	140.0000	0.00
P-9	J-8	J-9	3138.00	6.00	130.0000	0.00

NODE NAME	NODE TITLE	EXTERNAL	JUNCTION	EXTERNAL
		DEMAND (gpm)	ELEVATION (ft)	GRADE (ft)
AV-1		0.00	610.00	
AV-2		0.00	630.00	
J-1		9.00	607.00	
J-10		15.00	611.00	
J-11		45.00	610.00	
J-12		0.00	610.00	
J-14		0.00	610.00	
J-15		0.00	605.00	
J-16		0.00	605.00	
J-2		75.00	617.00	
J-3		0.00	605.00	
J-4		0.00	602.00	
J-5		45.00	613.00	
J-6		21.00	611.00	
J-7		0.00	613.00	
J-8		18.00	611.00	
J-9		30.00	615.00	
Pump-1		0.00	610.00	
R-1		----	605.00	610.00
R-2		----	630.00	630.00
RV-1		----	630.00	722.31
SDO-1		.00	610.00	
T-1	South Tank	----	630.00	750.00
T-2	North Tank	----	625.00	749.00

Section 2 - Class Exercises

Class Exercise 1 - Quick Start Example (Quickstart1.p2k)

Step 1 - Initial Preparation

Step 2 - System Layout

Step 3 - Analyze System and Review Results

Step 4 - Some Additional Simulations


See the Quick Start AVI's (1-4) on the www.kypipe.com web site.


This will guide you through the complete layout development, data entry, and hydraulic analysis of a simple pipe network. We recommend that you run Pipe2018 in as high a resolution as your monitor can display such that it can be comfortably read.

Step 1 - Initial Preparation


Initial steps include file selection, background preparation, and system data selections.

a. File Selection - You can access an existing data file or create a new one. In this demonstration we will create a new file. Click on File (main menu) and select 'New'. The New File setup screen appears. Select KYPipe.

b. System Data Selection – Go to the System Data  (KYnetic) or System Data | Simulation Specs menu (Classic). Select US Gallons per Minute for Units. The default head loss equation (Hazen-Williams) and other defaults are all acceptable. Click Okay.

Click  (KYnetic) or on the 'Map' tab (Classic) to return to the map view.

c. Background Preparation - You can import a drawing or map image, utilize grid lines or choose not to use a background. For this demonstration we will turn on a grid and use it to guide our layout letting Pipe2018 calculate pipe lengths.

Click on  (KYnetic) or Map Settings | Grids (Classic). The default grid settings of 1000 (major) and 100 (minor) are good for our demonstration so we will use them. Click on Major Grid and Minor Grid check boxes. This will display background grid lines. Return to the map view.

Step 2 - System Layout

The map area which appears on the screen will show a region approximately 1000 x 1000 feet with the 100-foot grid lines displayed. This area will be appropriate for the demonstration. A larger or smaller region can be displayed by clicking on the zoom in (+) or zoom out (-) buttons on the left side.

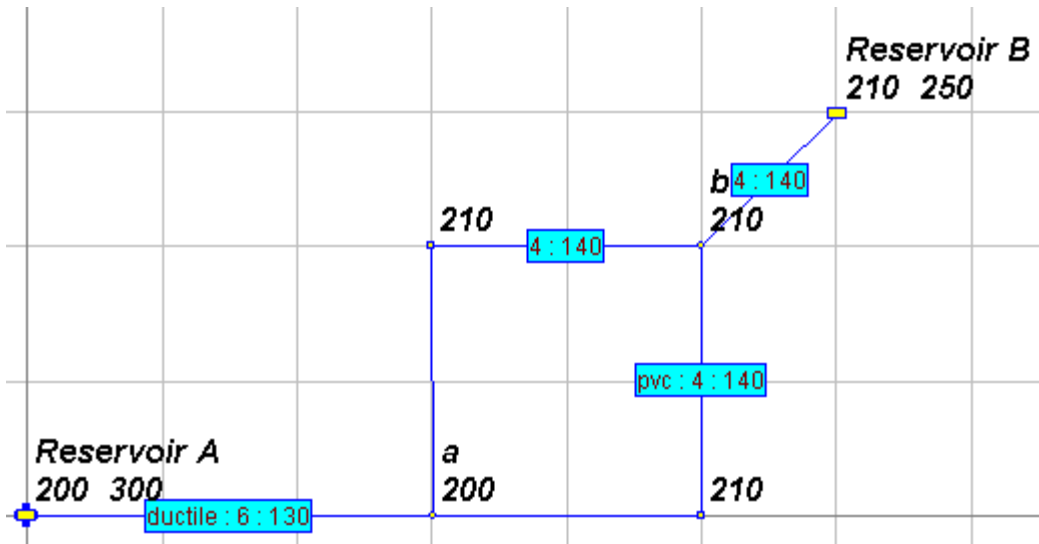


Figure CE1 - 1 Example pipe system

The system we wish to lay out is shown above. It is drawn on a 100-foot grid system. It is a loop fed by Reservoir A (Grade (or HGL) = 300') and discharges into Reservoir B (Grade (or HGL) = 250'). The node elevations are noted at all junctions first. This is followed by the reservoir grades at the two reservoirs. The pipe material, diameter and roughness are noted for each pipe in a box. Points (a) and (b) are shown for reference in the discussion below. The development of the pipe system model is accomplished in three steps.

a. Layout Pipes and Nodes - The entire piping system can be laid out using the mouse. A right click (RC) adds pipes and nodes and a left click (LC) selects a node. The following operations will produce the system layout:

- 1) RC on gridline intersection to make first node
- 2) move mouse 300 feet (3 blocks) to right and RC (a)
- 3) move mouse 200 feet up and RC
- 4) move mouse 200 feet right and RC
- 5) move mouse 200 feet down and RC (a)
- 6) move mouse 200 feet left (point to existing node) and RC
- 7) select node at (b) (LC) and move 100 feet up and 100 feet to left and RC

Now all the pipes and nodes are laid out. Note all nodes are either junction or intermediate nodes and Pipe2018 has assigned pipe and node names.

b. Change Node Types - Select any nodes which are different than shown and change to the correct node type. To do this select the node and click on the Node Type description or in Classic click the drop down node list (Node Information Window below Name) and select desired type from list.

- 1) Select node at Reservoir A (LC) and change node type to Reservoir (Grade type)

2) Select node at Reservoir B and change node type to Reservoir (Grade type)

The system should now look as shown below.

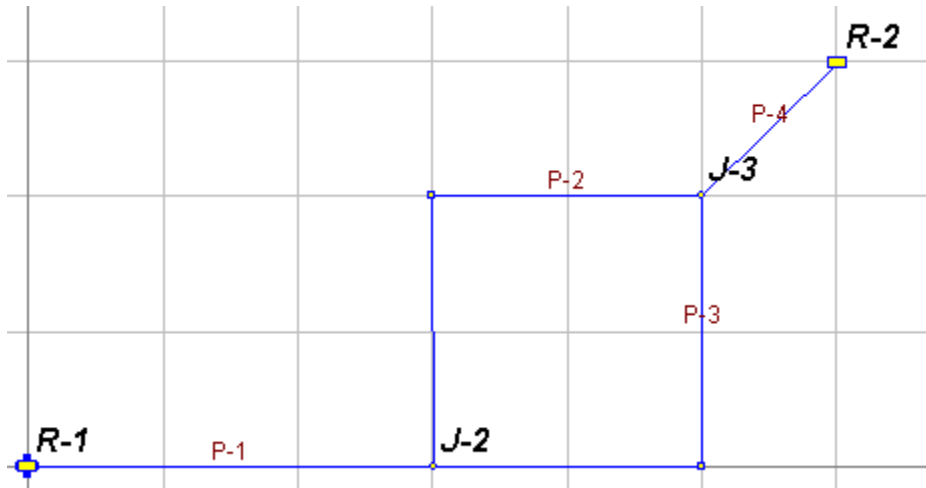


Figure CE1- 2 Completed pipe system layout

c. Provide Data - Select each pipe and end node and provide data

1) Select each pipe and click Pipe Type (Pipe Info Window) and select choice from drop down list. Select ductile iron (di) - 6 for pipe from Reservoir A and pvc - 4 for the rest. Note that default roughness values are provided. Provide appropriate Fittings Data (elbow for pipes with 90° bend, for example)

2) Select each Reservoir and provide values shown for Elevation and Grade (HGL).

3) Select each junction and intermediate node and provide Elevation.

d. Save Data File - Provide a name and save your data file. Click on File (Main Menu) and Save As and provide a file name in the popup menu, such as QS1 (for Quick Start example 1). Note a copy of this file may be loaded by clicking the Examples button and going to the Class Exercises 1 folder. It is called *QuickStart1.P2K*.


Step 3 - Analyze System and Review Results

a. Check Data and Run Analysis

1. Click Analyze (Main menu) and select Error Check. If errors are flagged correct these. If the message "No Errors" appears, proceed.

2. Click Analyze (Main Menu) and then Analysis. In the Analysis Setup box, make sure Analysis Type 'KYPipe' is selected and 'Use Current Year'. Click Analyze.

b. Review Results - The results can be reviewed on the schematic using Results Labels or by looking at the tabulated output.

1. Click on  or Report tab and scroll through the tabulated summary of data and results. Return to the Map.
2. Click on Labels (Main menu) and select Pipe Result A and Node Result A to show the results depicted in the Results Selection bar on the bottom right of the screen. You can change the pipe (P) results (default is Flow) and the node (N) results (default is Pressure). A helpful selection is Loss (head loss) for pipes and HGL for nodes because it provides a very useful view of the system operation. Printouts based on these selections are shown (Figure CE1-3 and 4).

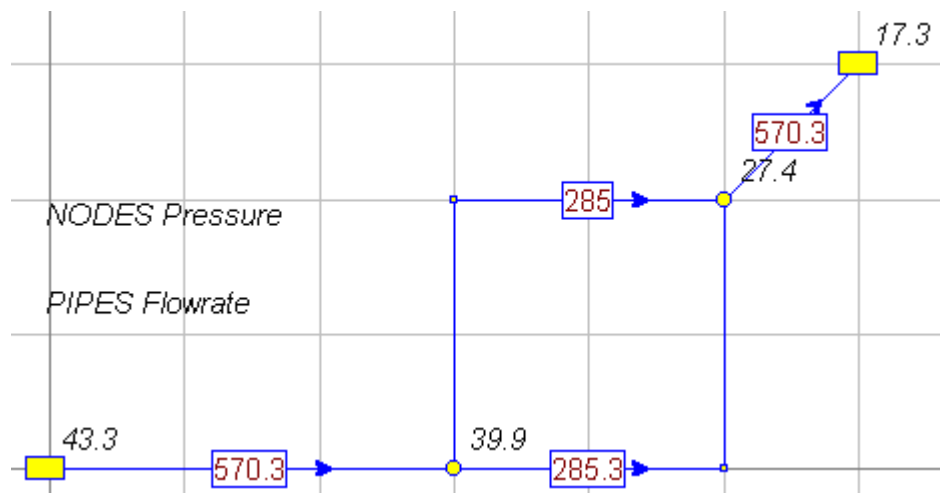


Figure CE1- 3 Case 1 - Pressure and Flow

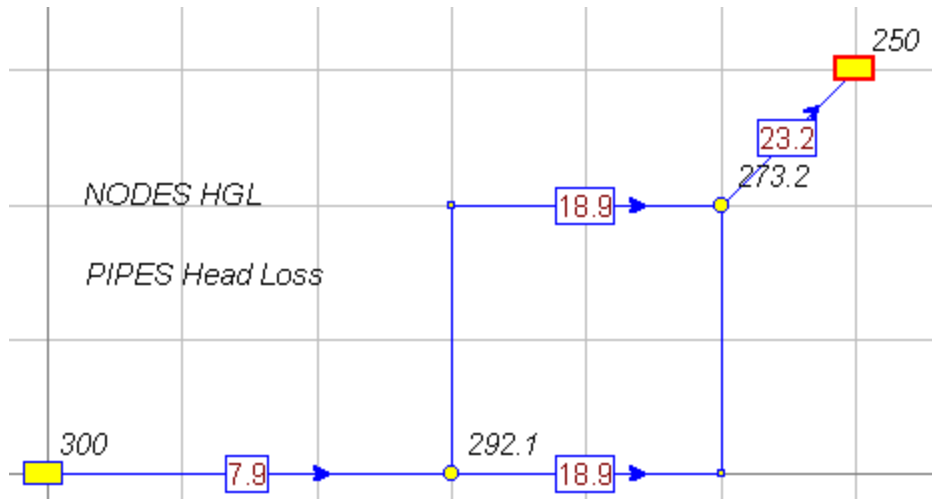


Figure CE1- 4 Case 1 - Loss and HGL

Step 4 - Some Additional Simulations (Quickstart2.p2k)

It is very easy to modify data and run a new simulation. Several are described:

Age-Based Roughness – If the roughnesses are fixed, do the following:

Under  Edit (Main Menu) click Select All Pipes.
Classic

In the Edit Pipe Set box, under Item to Edit, select Roughnesses.

Under Operation select Not Fixed.

Click Proceed.

KYnetic

Click the “Roughness” row heading

In the window that appears, under Group Edit, select Unfix (Calculate).

Click Apply Edit

Rerun the analysis but this time uncheck ‘Use Current Year’ to remove that requirement and enter the year 2043. The analysis now shows a significant change in pipe roughness due to aging and a substantial decrease in the capacity to transport water from Reservoir A to Reservoir B. A printout showing flows and pressures illustrate this (Figure CE1-5).

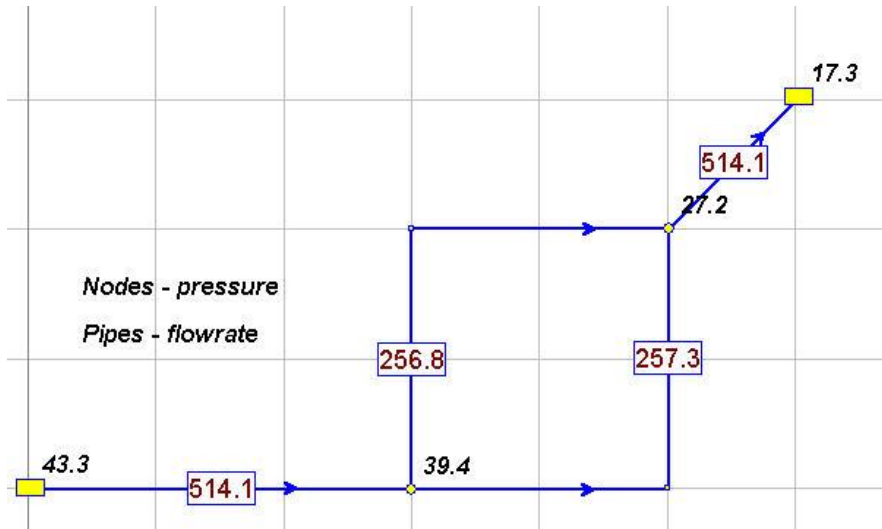
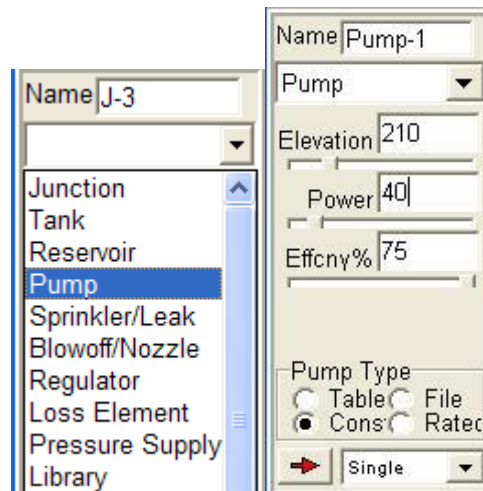
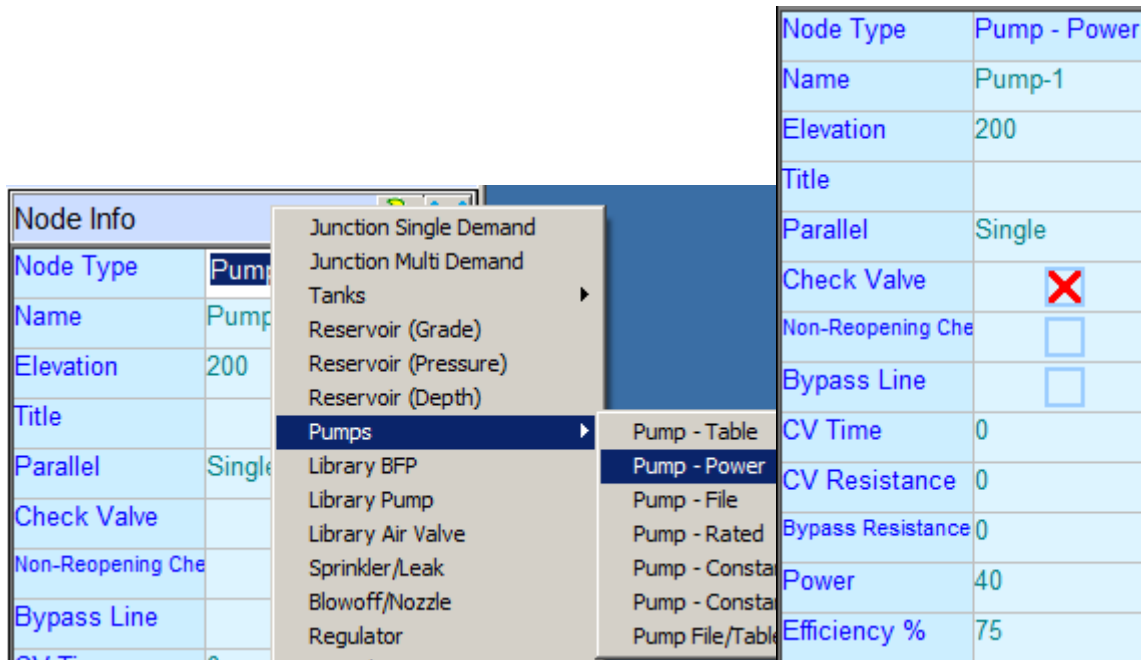


Figure CE1- 5 Case 2 - Year 2023

b. Add a Pump (*QuickStart2.P2K*) - We want to add a 40 HP (useful horsepower) pump in the line leading from Reservoir A about 100 feet from the reservoir. To do this, click on (LC) the pipe at the desired location and click on Insrt (Pipe Information Window button) and select Intermediate Node. Now in the map screen, select the intermediate node (LC on node) and change node type to Pump. Select the pump and select Constant Pwr (power) for Pump Type and input 40 (HP) for the Power and 210 (ft.) for the elevation (Node Information Window). These operations are shown in Figure CE1-6. Now analyze the system and note the effect of this pump which provides around 136 feet of head and nearly doubles the flow. A printout showing flows and pressures is shown (Figure CE1-6).



Classic



KYnetic

Figure CE1- 6 Case 3 – Adding a Pump

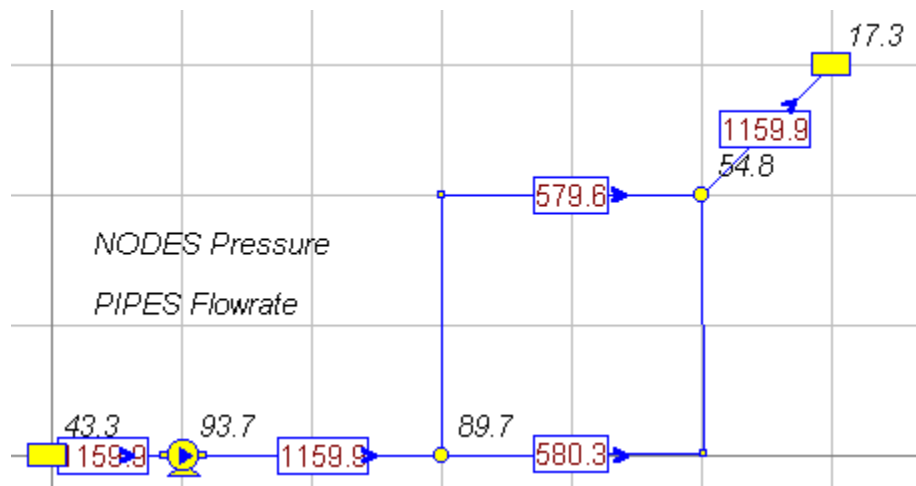


Figure CE1- 7 Case 3 – Results - Added Pump

QuickStart Example 2 – SI Units

Creating a Network Model

Dr. Don J Wood and Dr. Srin Lingireddy
KYPIPE LLC, Lexington, KY, USA
www.kypipe.com

Laying Out Your Pipe System

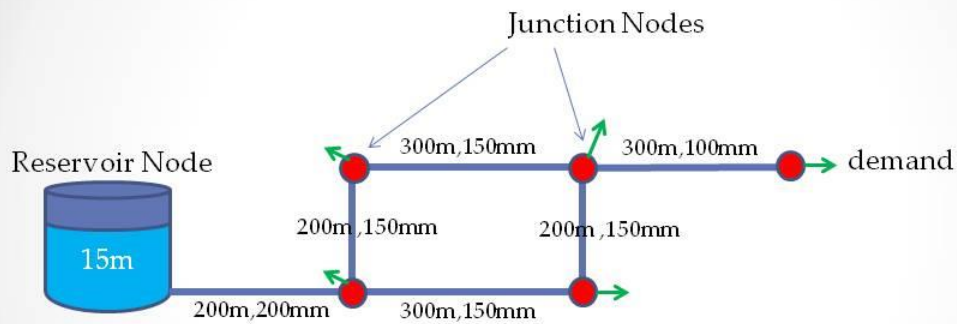
As Easy as 1-2-3

- **(1)** Left Click (LC) to select existing node (or pipe)
- **(2)** Select first node – move mouse and Right Click (RC) to add Pipe and Node
- **(3)** Select Node and use Dropdown List to change Node Type

Step-by-step Network Layout Example

...

Network Schematic

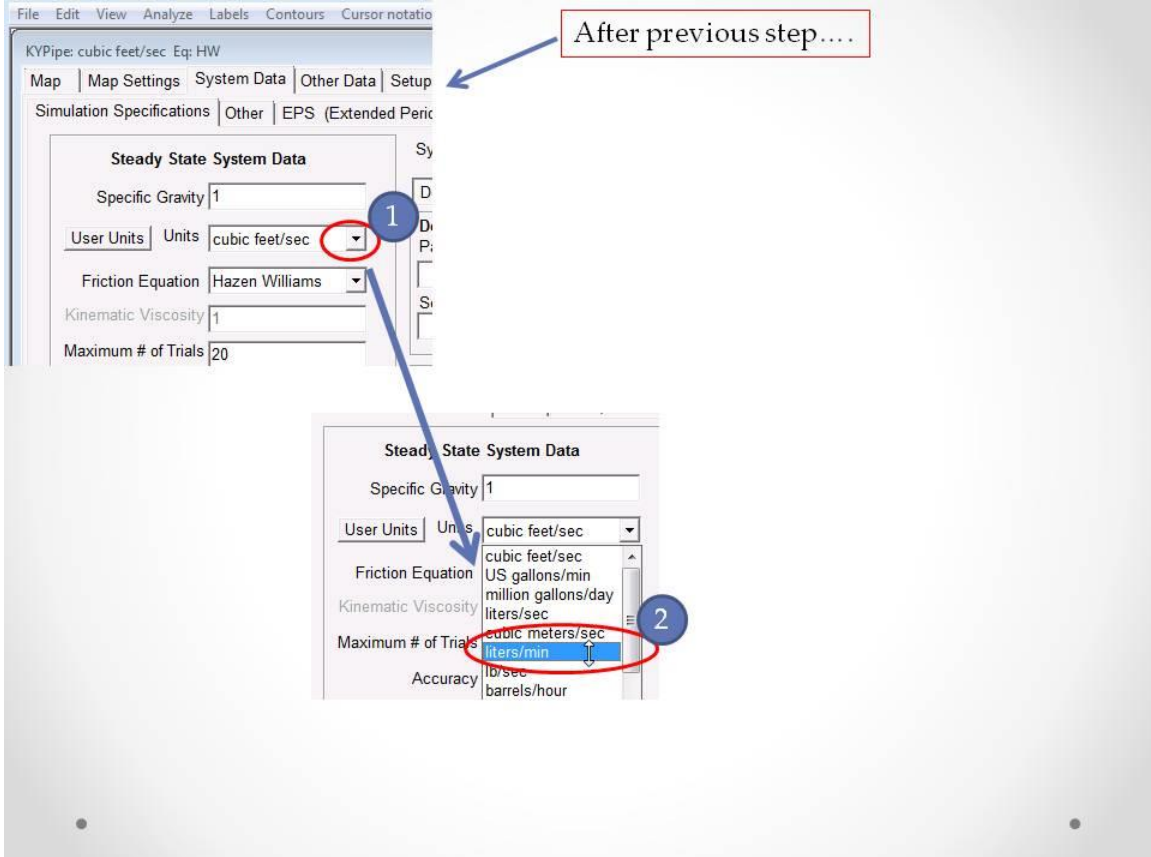
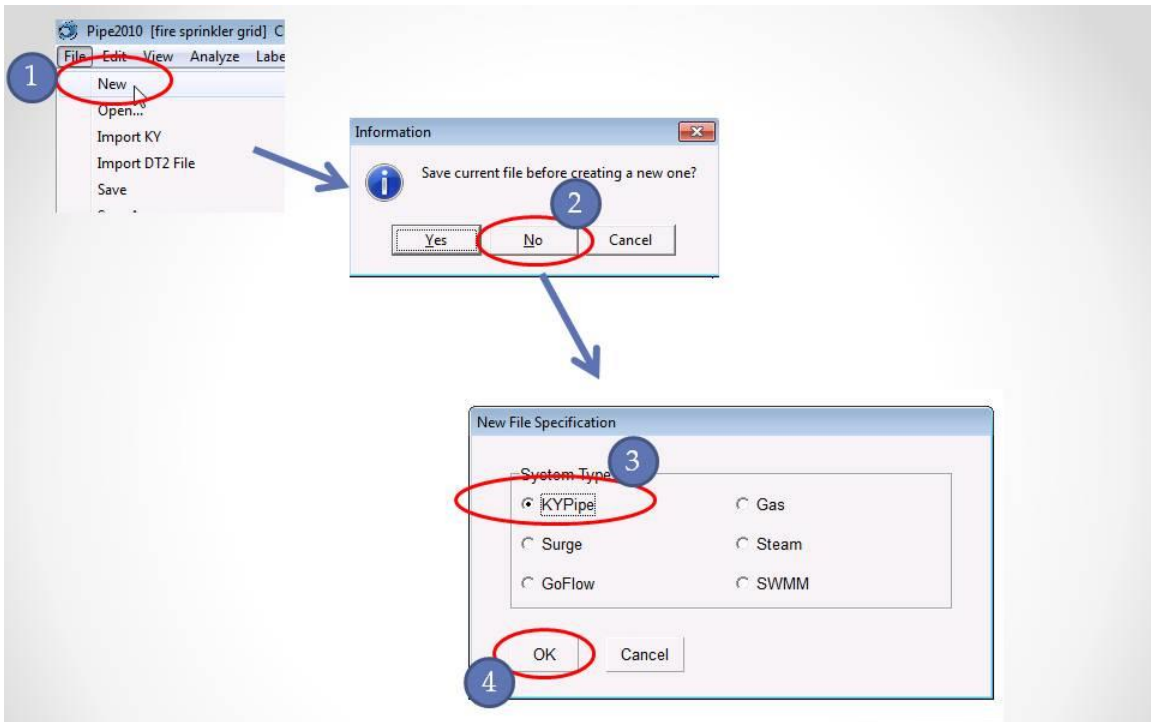


Elevation of all nodes = 100m

Depth of water in reservoir = 15m

Demand at all nodes = 500 lpm

Pipes: DI pipes, Hazen William Roughness Coefficient = 120



After previous step....

1 Major Grid
2 System Data
3 5000
4 100
5 Origin X
6 Origin Y
7 Snap To Grid
8 Use Snap Grid
9 Not Automatically

Steady State System Data

System Type: KYPipe

User Units: liters/min

Friction Equation: Hazen Williams

Kinematic Viscosity: 1

Maximum # of Trials: 20

Accuracy: 0.0001

Major Grid: 5000

Minor Grid: 100

Mark Origin:

Origin X: 0

Origin Y: 0

Pipe Prefix: P

Junction Prefix: J

Grid Size: 10

Use Snap Grid:

Snap All Now

Multiple Demand Types:

Do Not Save Previous Results:

Check for NAN and INF:

Use Valve Coefficient (Cv) instead of Resistance (R) for Active Valves:

View device inlets and outlets independently:

Reverse Arrow Buttons:

Pan Method 2:

Use Old Toolbar:

Not Automatically Layout Intermediate Node:

Empty grid after previous step

Right click

Left click

1 Move cursor to any grid point and RIGHT click – a junction node will be created as shown

J-1

Next step is to change junction node to reservoir node

The image shows a sequence of four screenshots illustrating the process of changing a node type in Pipe2010:

- Node Information dialog for 'J-1':** The 'Junction' type is selected in the dropdown menu.
- Node Information dialog for 'J-1':** The 'Reservoir' type is selected in the dropdown menu.
- Node Information dialog for 'R-1':** The 'Reservoir' type is selected. The 'Elevation' is set to 100 and the 'Depth' is set to 15.
- Pipe2010 main window:** The 'R-1' node is visible on the map.

Next step is to create a pipe and junction node 200m from reservoir node

Place cursor about 2 grid spaces from reservoir node and RIGHT click

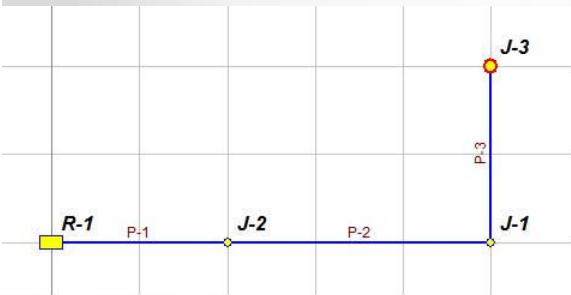
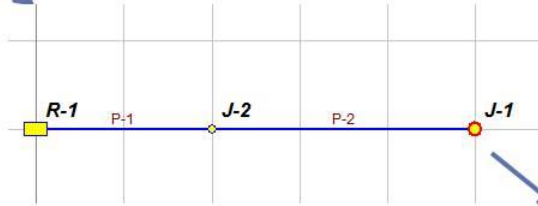
The diagram illustrates the process of creating a pipe and junction node:

- A reservoir node **R-1** is shown on a grid.
- A cursor is placed about 2 grid spaces to the right of **R-1**.
- A mouse icon indicates a right-click action.
- The resulting setup shows a pipe **P-1** connecting **R-1** to a new junction node **J-2**.

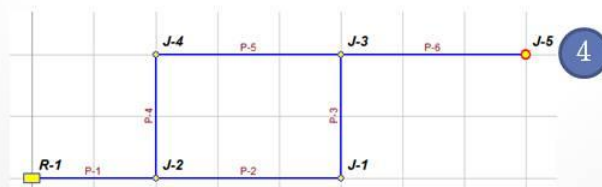
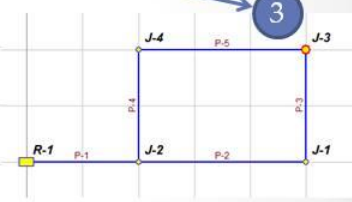
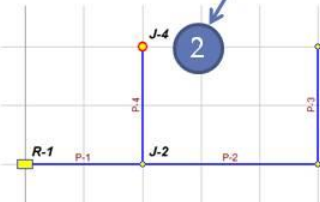
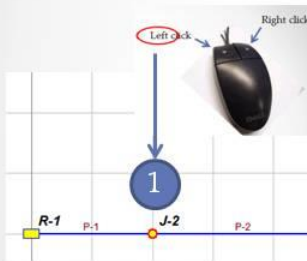
Repeat these steps to complete the layout process



Move cursor 3 grid spaces from junction node J-1 and RIGHT click



Now LEFT click on J-2 to select that node first and then create other pipes and nodes



Provide Data for Pipes and Nodes

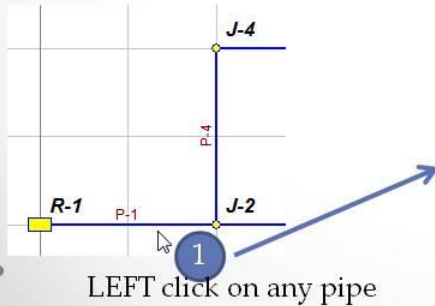
!!! This is where the beginners should use extreme caution on RIGHT and LEFT clicks !!!



RIGHT click adds a new node and pipe. **Accidental RIGHT click can generate unwanted nodes and pipes.** Sometimes the pipes may overlay each other and the user may not see this easily.



LEFT click is used for SELECTING a node or a pipe



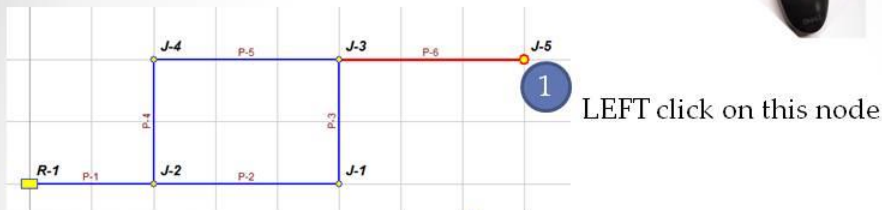
Pipe Information	
Del	More
Insert	Less
Right	User
Angle	Reset
Name P-1	
Pipe Type	
Diam	4
Mtrl	concrete
Rtng	
Length	200
Rough	125
Fittings	Closed
Other Data	
Node 1	R-1
Node 2	J-2
Reverse	
Residential Meters	0
Ref Year	2010
Pipe Title	

Name	P-1
Pipe Type	
Diam	200
Mtrl	DI
Rtng	
Length	200
Rough	120

Provide data

Provide Data for ALL pipes by selecting one pipe at a time

Next provide data for nodes:

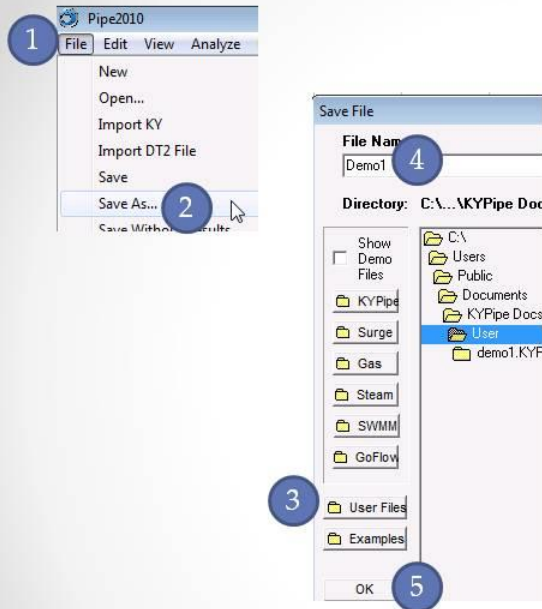


Node Information	
Del	More
Less	Right
User	Reset
Name J-5	
Junction	
Elevation	0
Demand	0
Dm Type	1
Node Image	
Show on Map	<input type="checkbox"/>
Show All	<input type="checkbox"/>
Large	Print
Full	Load
Clear	

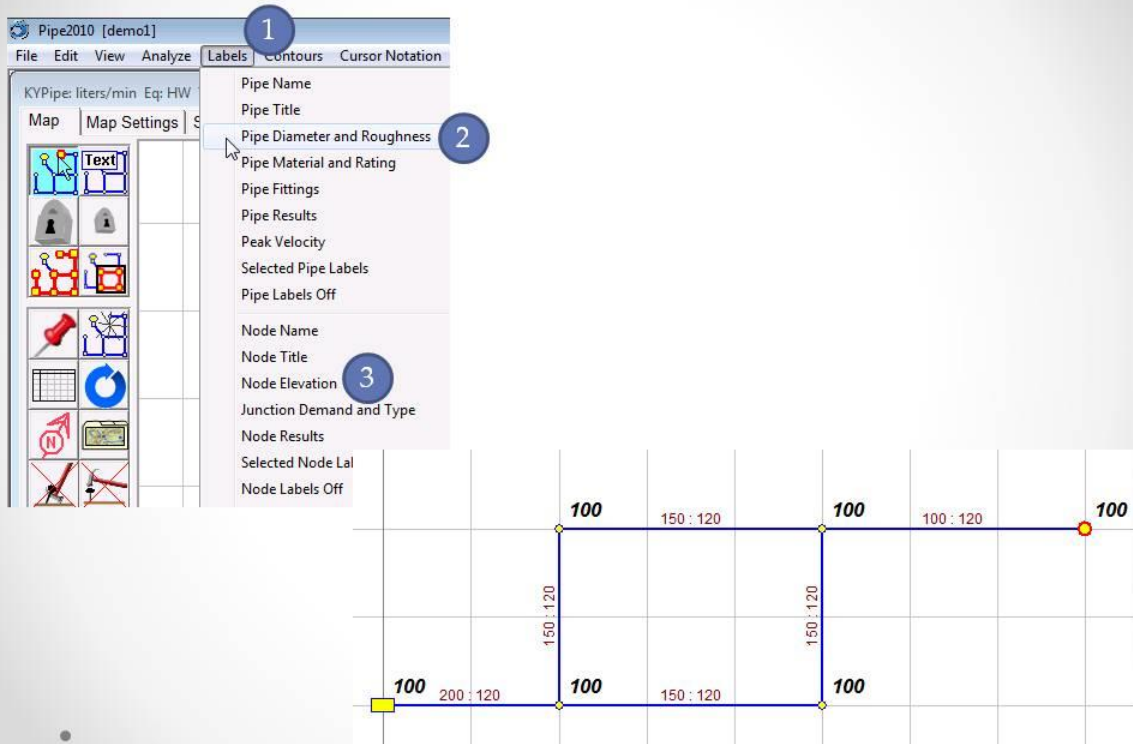
Node Information	
Del	More
Less	Right
User	
Name J-5	
Junction	
Elevation	100
Demand	500
Dm Type	1

Repeat these steps to provide data for ALL nodes

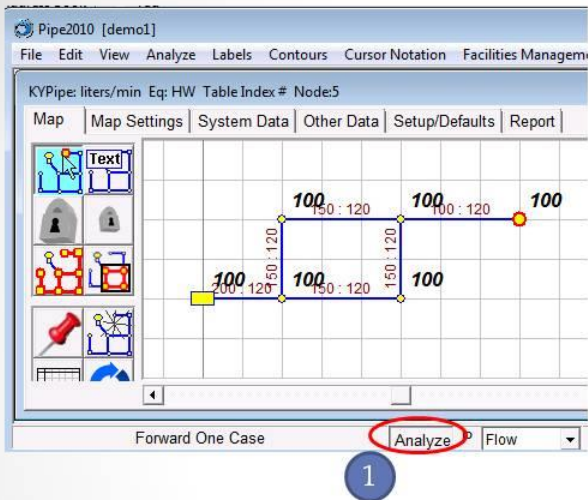
Save the model before further processing.



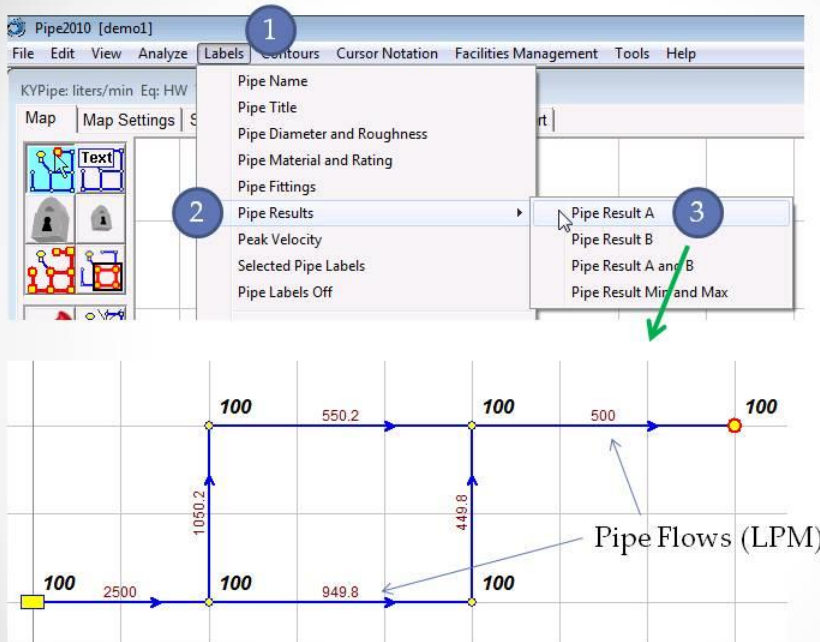
Review Model Data:

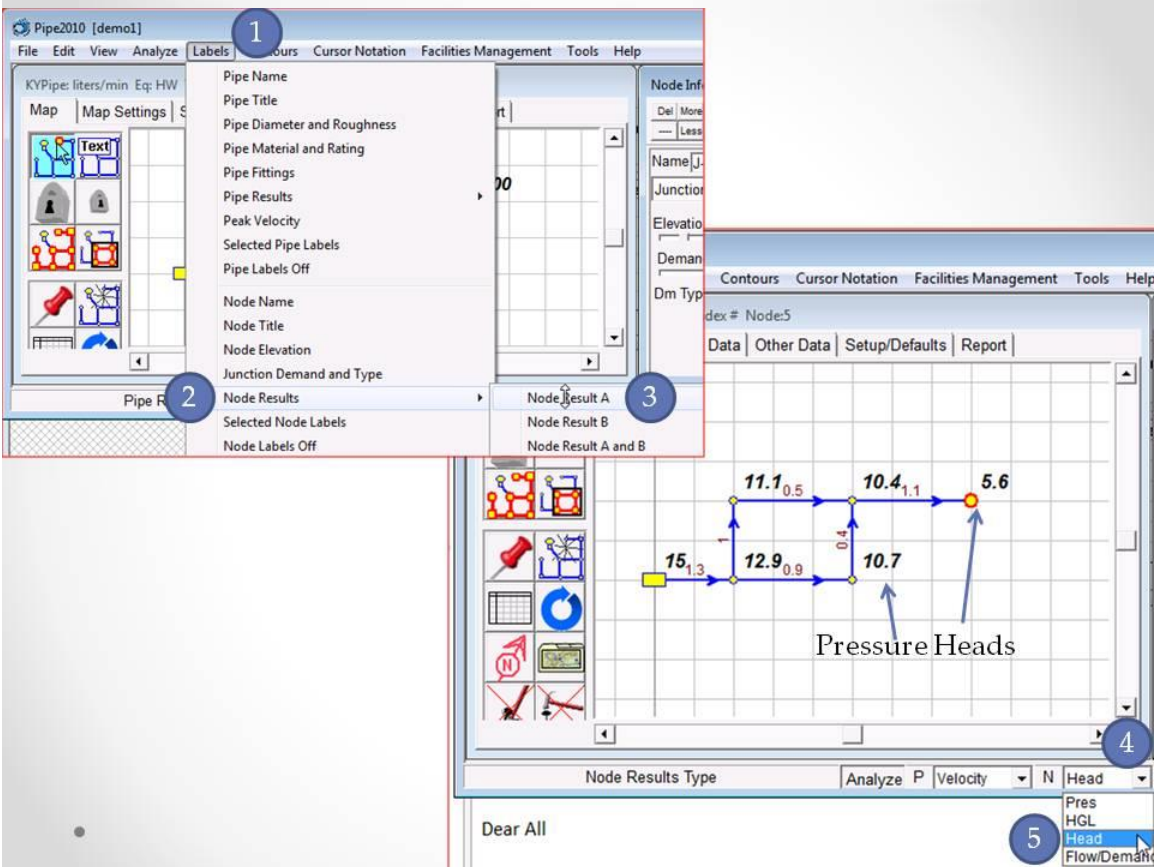
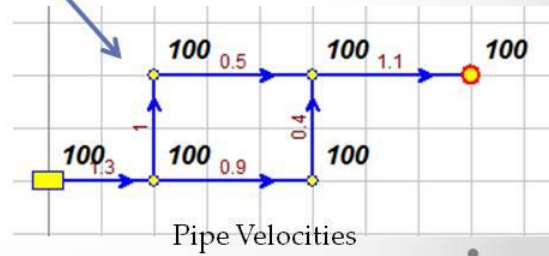
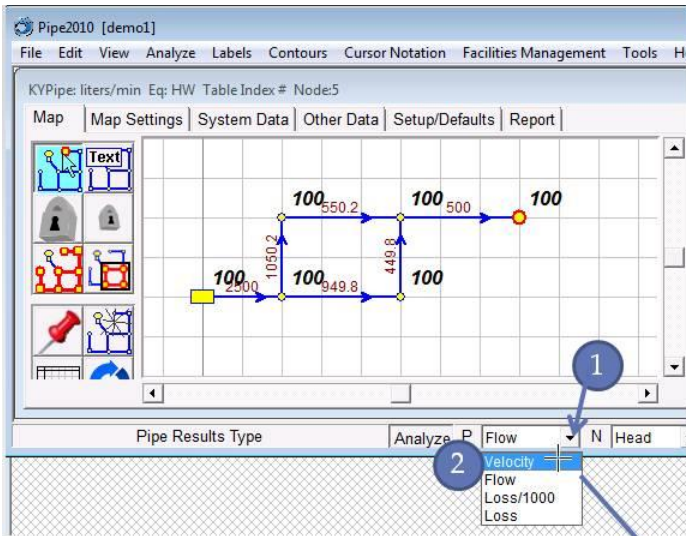


Steady state analysis:

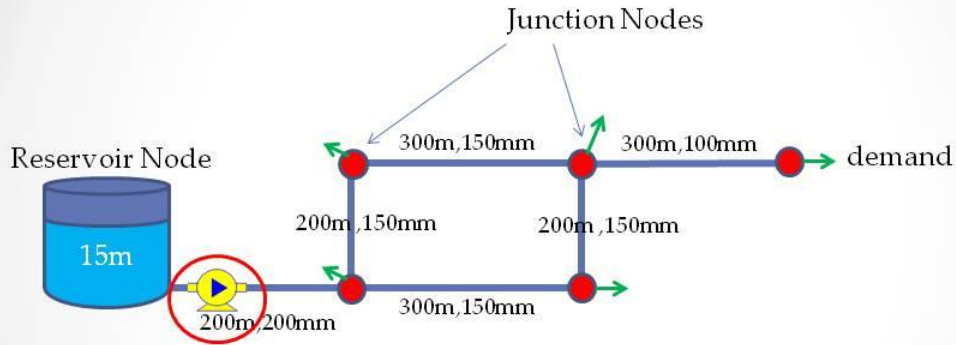


View Results





Add a 20kW Pump



Elevation of all nodes = 100m
 Depth of water in reservoir = 15m
 Demand at all nodes = 500 lpm
 Pipes: DI pipes, Hazen William Roughness Coefficient = 120

Left click on pipeline where the pump needs to be inserted

1

2

3

Pump inserted on pipe P-1

Left click

Right click

Pipe Information

Name P-1

Pipe Type

Diam 200

Mtrl di

Rtng

Length 200

Rough 120

Fittings Closed

Other Data

Node 1 R-1

Node 2 J-2

Reverse

Residential Meters 0

Ref Year 2012

Pipe Title

Check Valve

Hydrant

On/Off Valve

Metered Connection

Intermediate Node

Inline Meter

Device 1

Device 2

Junction

Pump

Tank

Reservoir

Regulator

Loss Element

Pressure Supply

Sprinkler/Leak

Blowoff/Nozzle

Active Valve

Vacuum Breaker

Class Exercise 2 – Water Distribution System (Example Base.P2K)

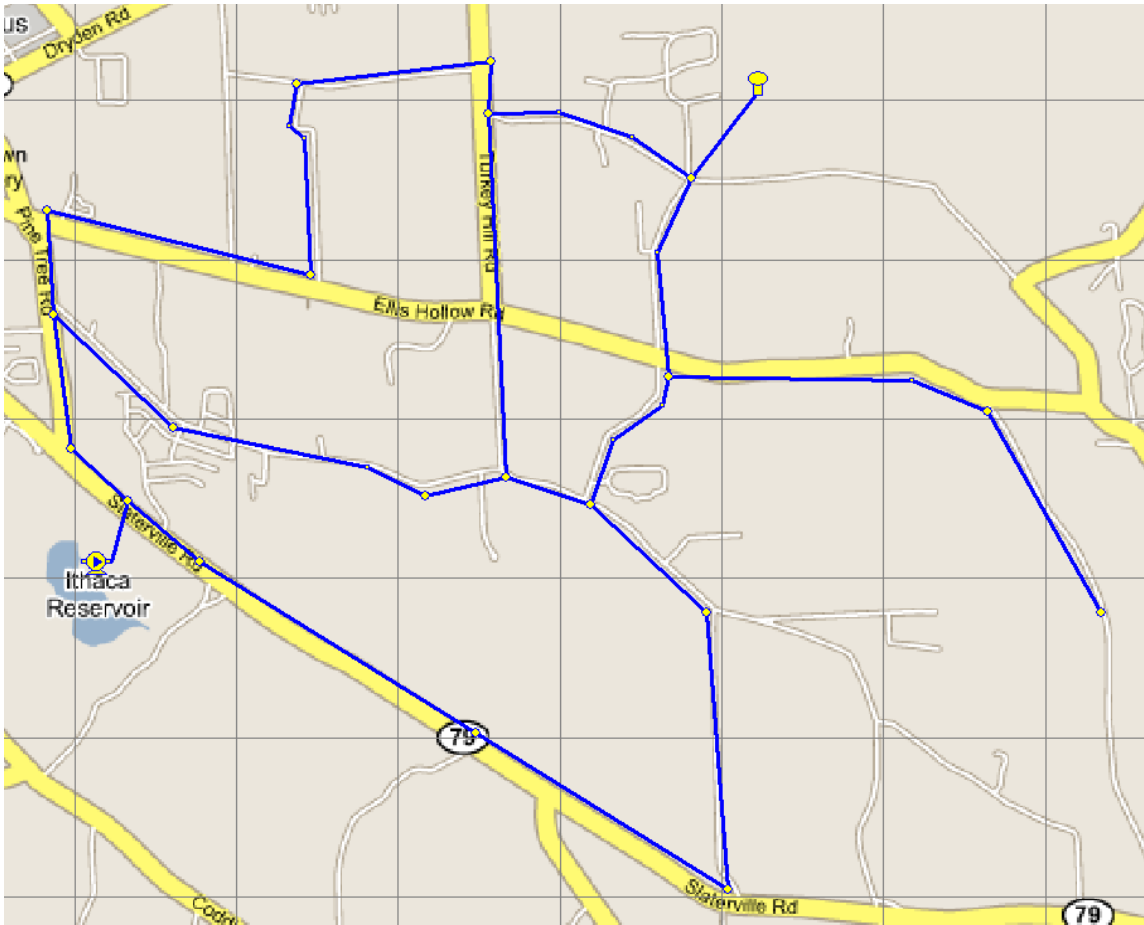


Figure CE2-1 Municipal Water System Layout

Description – Figure CE2-1 shows the basic layout for a drinking water distribution system. The water is supplied from a reservoir at a grade 120ft directly by a pump with the following head-flow pump characteristic data. An overhead storage tank is shown and has a water level of 250 feet.

Head(ft)	Flow(gpm)
200	0
180	500
150	800

The system is constructed of 6 inch ductile iron (red) and 4 inch pvc pipes and the roughness for new and 10-year old pipes are noted on Figure CE2-2. Key elevations are noted (1st number) and a scale (500 foot grid) is shown. A total demand of 600gpm is

distributed at five nodes as noted by the figures (2nd number). These demands represent the average daily demand requirements.

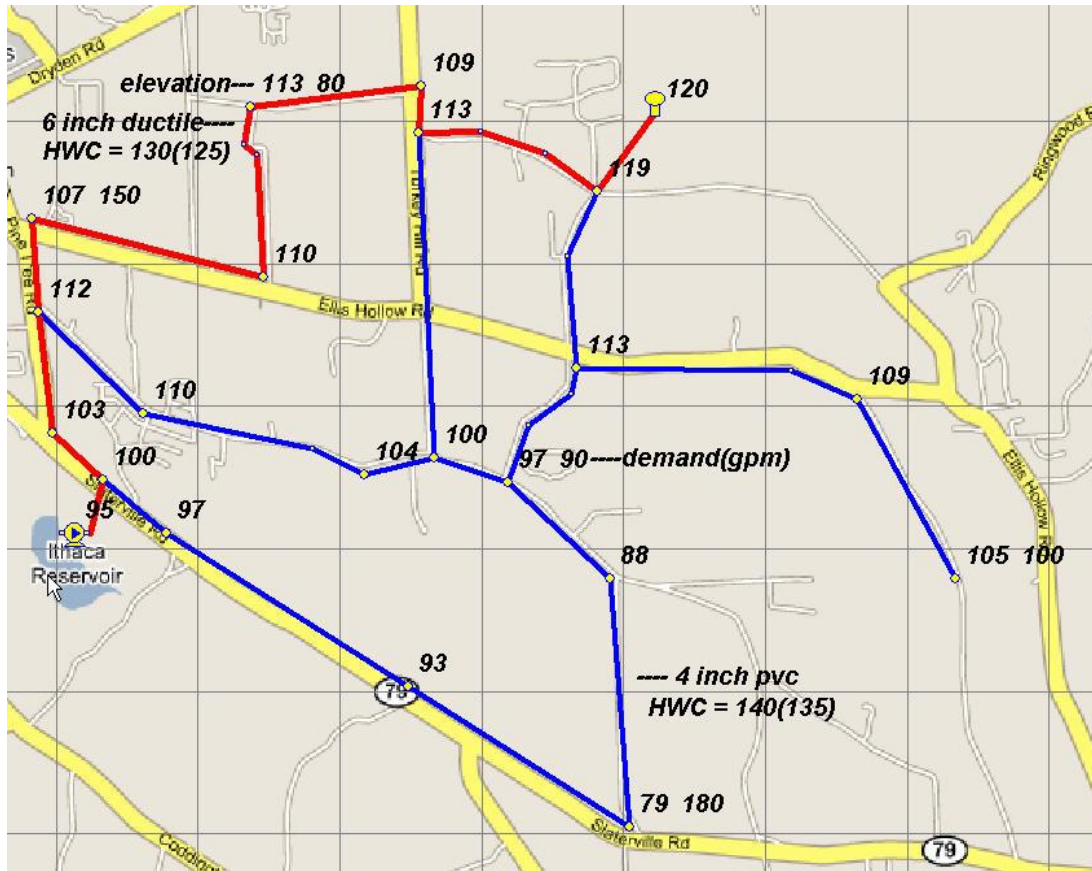


Figure CE2-2 Municipal Water System Data

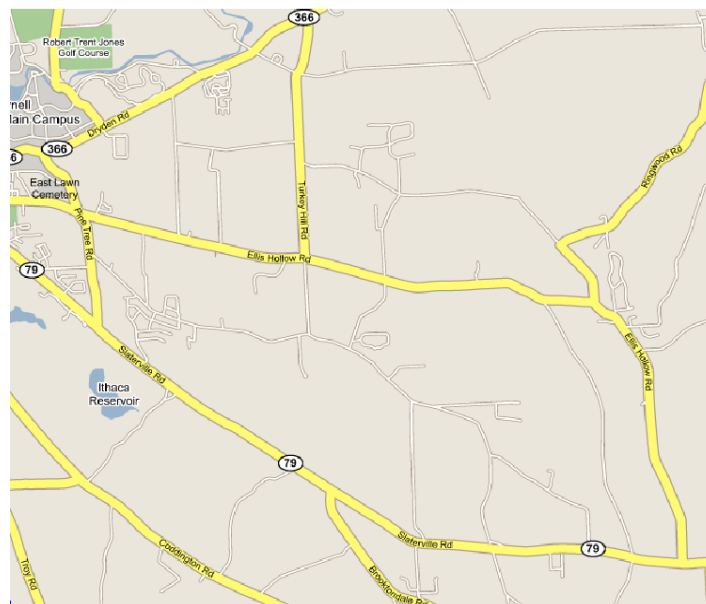




Figure CE2-3 Background Map (4500 feet wide)

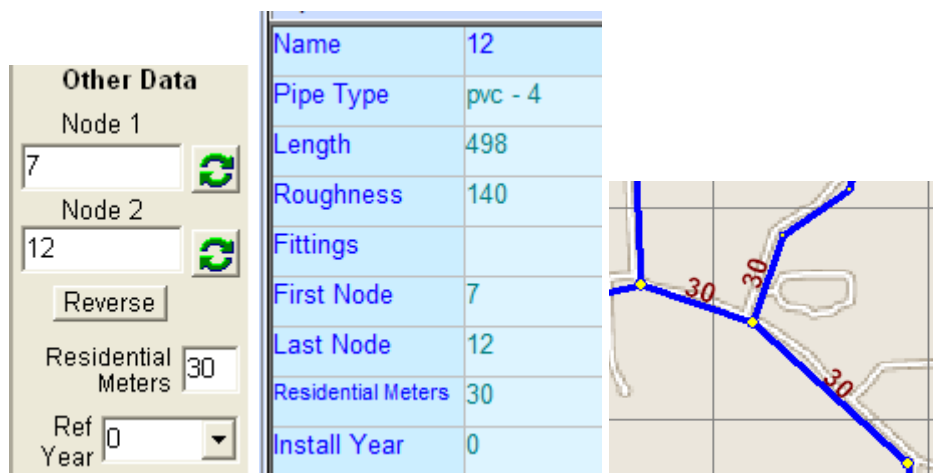
Regular Simulation Exercises

Carry out the following exercises using a data file called CE2map, which includes a background map file that is set to scale but no other data. This data file can be found in the File Open menu by Clicking on Examples button and browsing the Class Exercises 2 folder. Alternately you can open up a New file and import the background map (ce2map.bmp). The may be found by clicking “Add Demo Map” in the Backgrounds menu. This map is not scaled. However, you can easily scale it by noting that the scaled distance from the SW corner to the SE corner is 4500 feet. To scale the map just lay out a pipe line from the SW to SE corner and note the length on the unscaled map (Lmap). A scale factor of $4500/Lmap$ must then be entered for the Pipe Scale Factor (XY). This is found in the Other menu  or System Data | Other tab. Once you have a scaled background map the exercises below can be done.

a) Layout the piping system for this pipe network using the background map to locate the nodes and the map scale to set pipe lengths. When finished Click File | Save As and on the Save File menu under File Name provide a name for your data file (eg. **Example Base.P2K**)

b) Provide data and analyze the network using the baseline data. The storage tank initial level (hydraulic grade) should be set to 250ft for this simulation. The results for pressures for the analysis of the baseline data are shown in Figure CE2-5.

c) Replace the 600gpm demand by 600 residential meters, using as average residential demand of 1.0gpm each. Do this by indicating the number of meters on the pipe links, which connect the nodes with demand points. Divide the demand equally among the connecting pipes. For example, if 3 pipe links connect a junction node with a 90gpm demand, set 30 residential meters on each pipe link as shown below. Don't forget to set the demand at the junction nodes to zero and the Average Residential Demand to 1.0 gpm (Other menu  or System Data | Other).



The screenshot displays the software interface for pipe network simulation. On the left, the 'Other Data' panel shows settings for a pipe link between Node 1 (7) and Node 2 (12). The 'Residential Meters' field is set to 30. The 'Ref Year' is set to 0. In the center, a table lists the pipe properties:

Name	12
Pipe Type	pvc - 4
Length	498
Roughness	140
Fittings	
First Node	7
Last Node	12
Residential Meters	30
Install Year	0

On the right, a map shows a pipe network with blue lines. A junction node is highlighted with a yellow dot, and three pipe links radiate from it. Each link is labeled with the number '30', representing the number of residential meters assigned to that link.

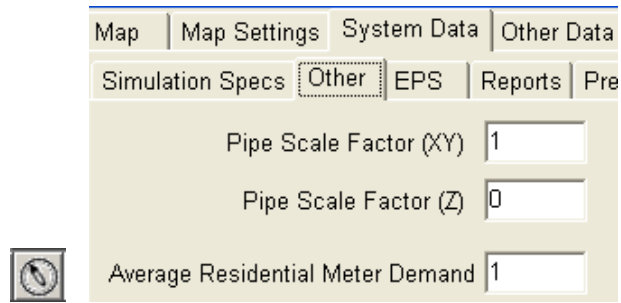
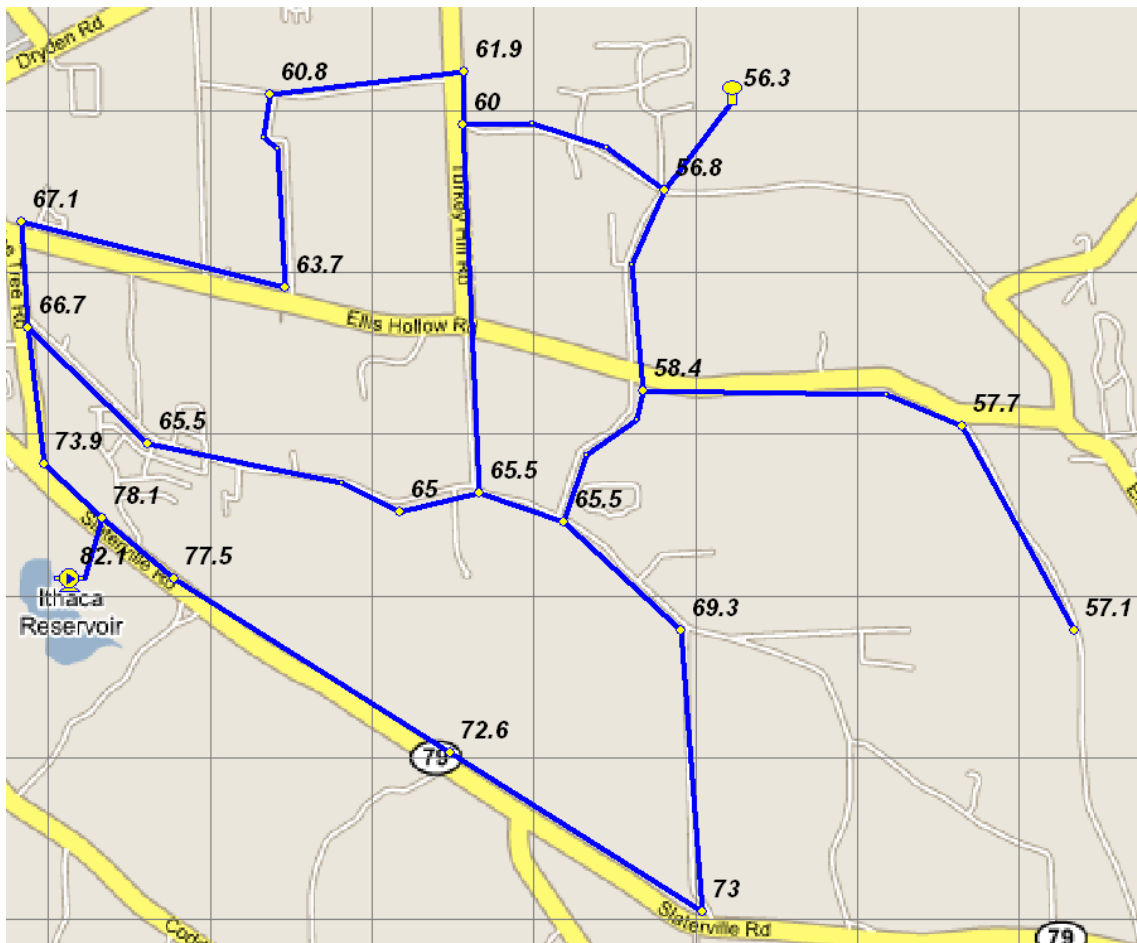


Figure CE2-4 Using Metered Connections for Demand Data

Results – The pressures for the baseline data with demands (b) are shown below. The pressures obtained using meters will be the same or very close to these values.



**Figure CE2-5 Results for CE2 (b)
EPS Exercises**

Extended Period Simulations (EPS) (example eps 24-hour.p2k, 2 and 3)

Setup and run the following EPS simulations.

EPS1 - Assume the tank is a 30ft diameter cylindrical standpipe with 260ft overflow (maximum) and 220ft bottom (minimum) elevations (hydraulic grades). The tank initially starts full at 8:00AM. Setup and run a 24hour extended period simulation using a demand pattern shown in the attached table. The pump stays on at all times.

EPS2 - Set up Change Data for the pump such that it is on when the GDF is ≥ 1.0 (hours 0-8 and 10-16) and off when the GDF < 1.0

EPS3 - Set up a control switch to turn the pump off when the level is 255 feet and on when the level is 225 feet.

EPS4 - Repeat the analysis EPS3 with the baseline demands increased by 50%

Actual Time	Simulation	
	Time	Demand Mult. Fact.
8:00 AM	0	1
9:00 AM	1	1.1
10:00 AM	2	1.2
11:00 AM	3	1.3
12:00 PM	4	1.4
1:00 PM	5	1.5
2:00 PM	6	1.3
3:00 PM	7	1.1
4:00 PM	8	0.9
5:00 PM	9	0.7
6:00 PM	10	1
7:00 PM	11	1.3
8:00 PM	12	1.6
9:00 PM	13	1.65
10:00 PM	14	1.4
11:00 PM	15	1.1
12:00 AM	16	0.8
1:00 AM	17	0.4
2:00 AM	18	0.2
3:00 AM	19	0.2
4:00 AM	20	0.5
5:00 AM	21	0.7
6:00 AM	22	0.8
7:00 AM	23	0.9

Figure CE2-6 Demand Pattern for EPS runs for CE2

Map | Map Settings | System Data | Other Data | Setup/Defaults | Report |

Simulation Specs | Other | EPS | Reports | Preferences | Skeletonize/Subset |

Use EPS

Total Time (hrs) Starting Time (hrs 0-24)

Computational Period (hrs) Report Time Style

Report Period (hrs)

Figure CE2-7 Demand Pattern for EPS runs for CE2



or Setups/Defaults | Demand Patterns

Time/Change	0	1	2	3	4	5	6	7	8	9	10	11	
Power Cost													
Residential													
Type 1	1	1.1	1.2	1.3	1.4	1.5	1.3	1.1	0.9	0.7	1	1.3	
11	12	13	14	15	16	17	18	19	20	21	22	23	
	1.3	1.6	1.65	1.4	1.1	0.8	0.4	0.2	0.2	0.5	0.7	0.8	0.9

Figure CE2-8 Demand Pattern Setup for EPS runs for CE2

Name

Fixed Diameter

Tank

Elevation

Max Level

Min Level

Initial

Inflow


Node Type	Tank Fixed Diameter
Name	TANK-A
Elevation	120
Max Level	0
Min Level	0
Initial Level	250
Inflow	0
Title	
Diameter	1
On/Off	<input checked="" type="checkbox"/>

Figure CE2-9 Overhead Tank Setup for EPS runs for CE2

Setting up the EPS – Three steps are normally required for converting the baseline system into an EPS file.

- 1) EPS System Data is required as shown in Figure CE2-7 (or System Data/EPS setup screen). The Total Time, Computational Period and the Starting Time should be

specified. This setup calls for a 24 hour simulation using a one hour increment and the simulation start time is 8 AM. This time is chosen to coincide with the Demand Pattern shown in Figure CE2-6.

- 2) The Demand Pattern data is entered on the Demand Pattern screen ( or Setups/Defaults | Demand Pattern) as shown in Figure CE2-8.
- 3) Tank Data must include the Maximum, Minimum and Initial levels as well as either a tank diameter or a volume and shape ID as shown in Figure CE2-9.

Node Changes		Changes for PUMP-1		
Cut Copy Paste Clear		Time	Change	Value
8	C Close	8	Closed	Close
10	O Open	10	Open	Open
16	C Close	16	Closed	Close


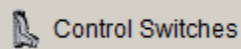
Figure CE2-10 Pump Changes for EPS2 - CE2

EPS Results

EPS1 – The EPS1 simulation can now be run. This run considers a situation where the pump is operated continuously for the entire 24 hour period. (*Example EPS 24-hour.P2K*)

EPS2 – Change Data is added for the pump to turn the pump off whenever the Global Demand Factor (GDF) is less than 1. This occurs from hours 8-10 and 16 – 23 and the Change Data screen for the pump is shown in Figure CE2-10. The results for EPS1 and EPS2 are shown in Figure CE2-11 which compares the two cases. Note the capability to show a Previous Result is very useful for comparing cases such as these.

The upper trace is for EPS1 where the pump operates continuously and the tank is filled and will be shut off from hour 20 on. (*Example EPS 24-hour2.P2K*)

EPS3 – This illustrates the use of a Control Switch to control the on/off status of the pump. The pump turns on when the HGL level drops below 225 feet and turns off when the level exceeds 255 feet. The setup for this device is shown in Figure CE2-12 ( -  or Other Data/Control Switches). The tank level for this situation is shown in Figure CE2-12. This plot shows that the pump turns off at around 18 hours into the simulation. (*Example EPS 24-hour3.P2K*)

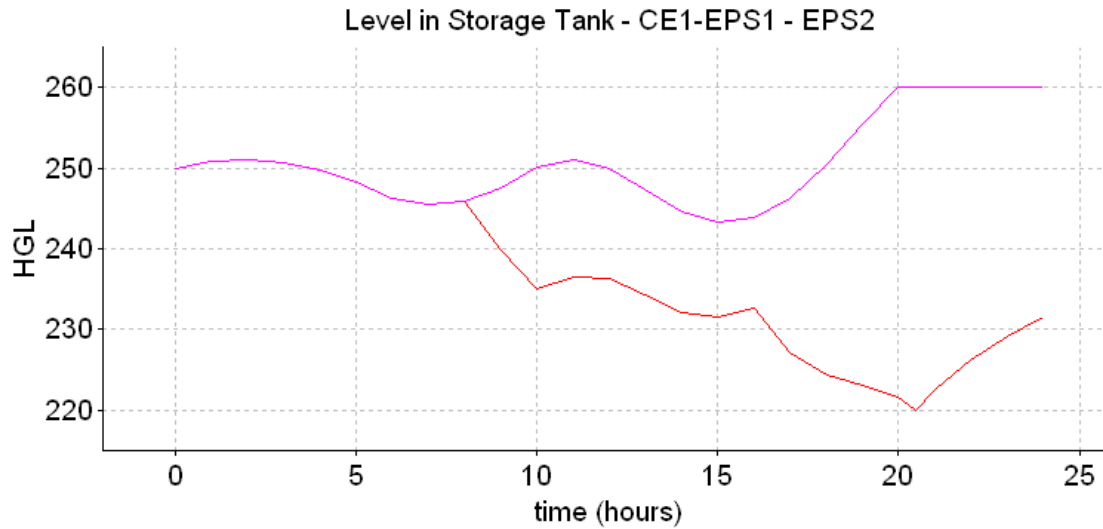


Figure CE2-11 Overhead Tank Level for EPS1 & EPS2 for CE2

Switch Units

controlled element	is	on/off	when	sensing node	is	below/between	low level	and	on/off	when	above	high level
PUMP-1	is	on	when	TANK-A	is	below	225	and	off	when	above	255

Figure CE2-12 Control Switch Setting for EPS3

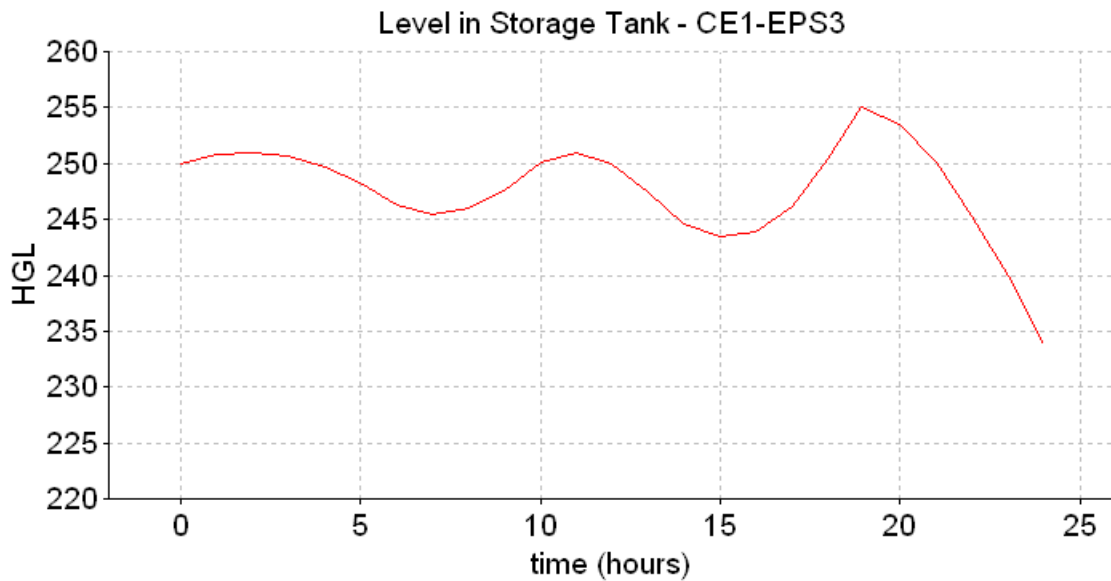


Figure CE2-13 Overhead Tank Level for EPS3

Surge Exercises

Set up and carry out the following surge analyses

Surge1 (Example Surge Rapid Shutdown.P2K)- A rapid rundown of the pump following a power outage. Utilize the Baseline demands and tank level and consider the both Fixed Demands and Pressure Sensitive Demands.

Surge2 (Example Surge Compressor Tank.P2K) – Repeat Surge1 with closed compressor surge tank attached just downstream from the pump. The surge tank has a 4 foot long 6 inch connection with one elbow and the compressor is designed to maintain 50 cubic feet of air while the pump is operating. Utilize the results of this exercise to size and precharge a bladder tank which will perform comparably.

Surge 1 Setup (example surge rapid shutdown.p2k)

Setting up the Surge Analysis – With some minor changes your baseline data file can be modified to carry out a surge analysis. The following steps are required.

The System Type must be changed to Surge and additional System Data provided. Figure CE2 – 14 shows this screen. The Total Simulation Time should be specified and for this exercise a 60 second simulation is specified.

The wave speed for the pipes must be defined. For this exercise two types of pipes are modeled. The 6 inch ductile pipe has a wave speed of approximately 4000 ft/sec. and 1500 ft/sec for the 4 inch pvc pipe. These wave speeds are set by using 1500 ft/sec as the Default Wave Speed as shown in Figure CE2-14. All pipes will automatically be assigned this value if the wave speed is not specifically defined for a pipe. Using Pipe2018's Global Set selection and editing capabilities the wave speed for the ductile iron pipes are set as shown in Figure CE2-15. All 6 inch pipes are selected as shown and the Wave Speed for this group set to 4000 ft/sec as shown. All others will be set to the 1500 ft/sec. (default) and this value will appear in the Pipe Data box as shown in Figure CE2-15.

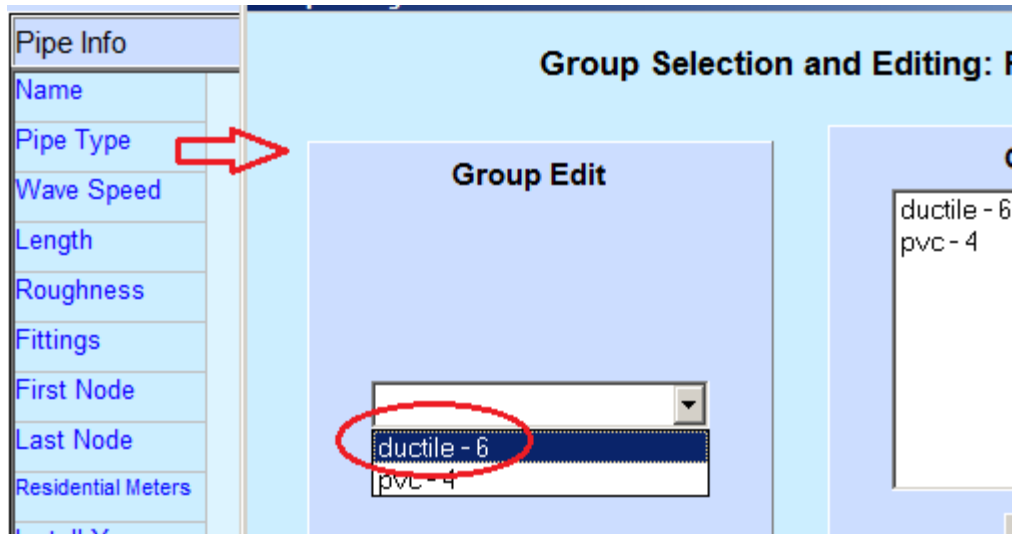
Change Data is required to define the cause of a transient event. For this case a 2 second rundown for the pump is set up as shown in Figure CE2-16. This data specifies that the pump run at full speed (speed ratio = 1.0) for the first 2 seconds and then ramp down to zero in the next 2 seconds. It is recommended that the initial steady state conditions be maintained for a short period (as this does for 2 seconds) to verify that the system steady state is being maintained prior to the start of the transient. Also, as shown in Figure CE2-16 if not done previously a check valve should be specified for the pump if this device is present to prevent reverse flow. Without a check valve flow will reverse through the pump when the speed is reduced.

Surge System Data		System Type
Specific Gravity	<input type="text" value="1"/>	Surge
User Units	Units: <input type="text" value="GPM"/>	<input type="button" value="Additional Data"/>
Equation	<input type="text" value="Hazen Williams"/>	Demand Calculation
Kinematic Viscosity	<input type="text" value="0"/>	<input type="text" value="Fixed Demands"/>
Length Accuracy	<input type="text" value="50"/>	Exit Head: <input type="text"/>
Total Simulation Time	<input type="text" value="60"/>	<input type="text" value="Do not calculate intrusion"/>
Cavitation Head	<input type="text"/>	Leakage Factor: <input type="text"/>
Time Step Increment	<input type="text"/>	Wave Speed
		Attribute used for pipes "Wave Speed"
		<input type="text" value="wave speed"/>
		Default Wave Speed: <input type="text" value="1500"/>

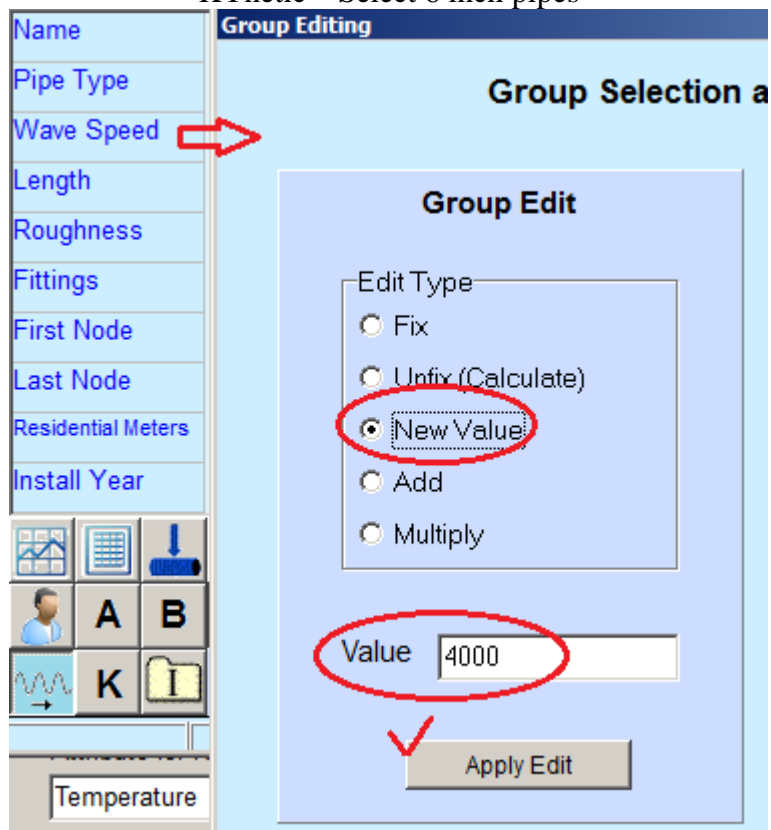
Figure CE2-14 System Data / Simulation Specs – Surge1

Edit Pipe Set	Set Selection
Pipe Status <input type="radio"/> Open <input type="radio"/> Closed	Diameter: <input type="text"/>
Item to Edit <input type="text" value="wave speed"/>	Value(s) <input type="text" value="0"/> <input type="text" value="4"/> <input type="text" value="6"/>
Operation <input type="text" value="New Value"/>	<input type="button" value="New Set"/>
Value: <input type="text" value="4000"/>	<input type="button" value="Add To Set"/>
<input type="button" value="Proceed"/>	<input type="button" value="Select from Set"/>
	<input type="button" value="Remove from Set"/>

Classic – Select all 6 inch pipes, then edit Wave Speed



KYnetic – Select 6 inch pipes



KYnetic – Edit Wave Speed

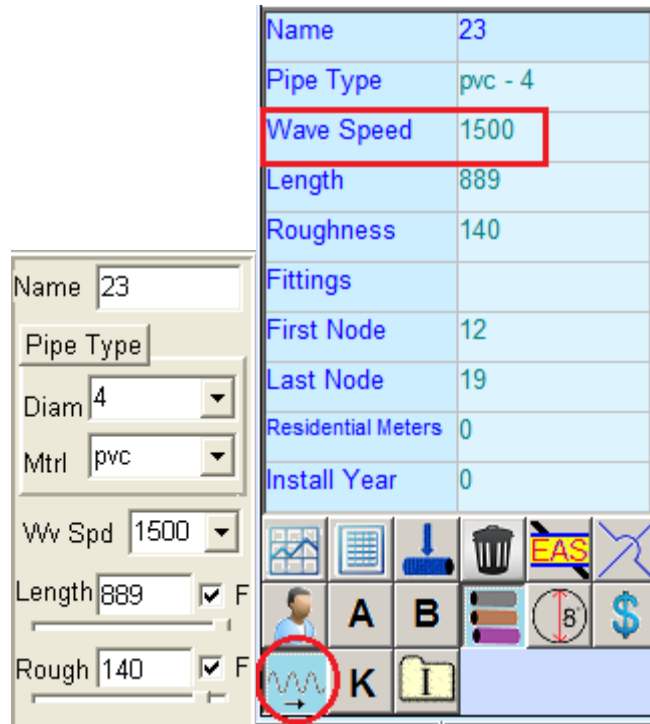
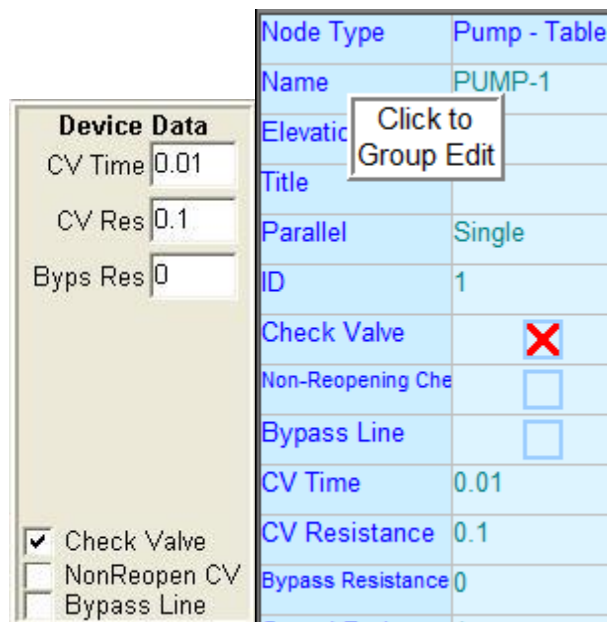


Figure CE2-15 Defining Wave Speed – Surge1




Additional Pump Data

Node Changes			Changes for PUMP-1		
Cut Copy Paste Clear					
Time/Case		Value	Time	Change	Value
0	s	1	0	speed ratio	1
2	s	1	2	speed ratio	1
4	s	0	4	speed ratio	0

Pump Rundown Data

Figure CE2-15 Defining Pump CV and Changes for Rundown – Surge1

Surge 1 Results – The pressure vs time plot for the dead end node (right side of system) is shown in Figure CE2-17. The blue trace is the result for Fixed Demands. When demands are fixed they remain constant even when the pressure is reduced. Pressure Sensitive Demands vary with pressure and will be reduced as the pressure goes down. This will have a very significant effect on the pressure transient. This option is implemented on the  or System Data/Simulation Specs screen as shown on Figure CE2-16. The same result (pressure at the dead end) is shown as the red trace on Figure CE2-17 using Pressure Sensitive Demands.

Demand Calculation

Pressure Sensitive ▼

Exit Head

Do not calculate intrusion ▼

Leakage Factor

Figure CE2-16 Defining Pressure Sensitive Demands – Surge1

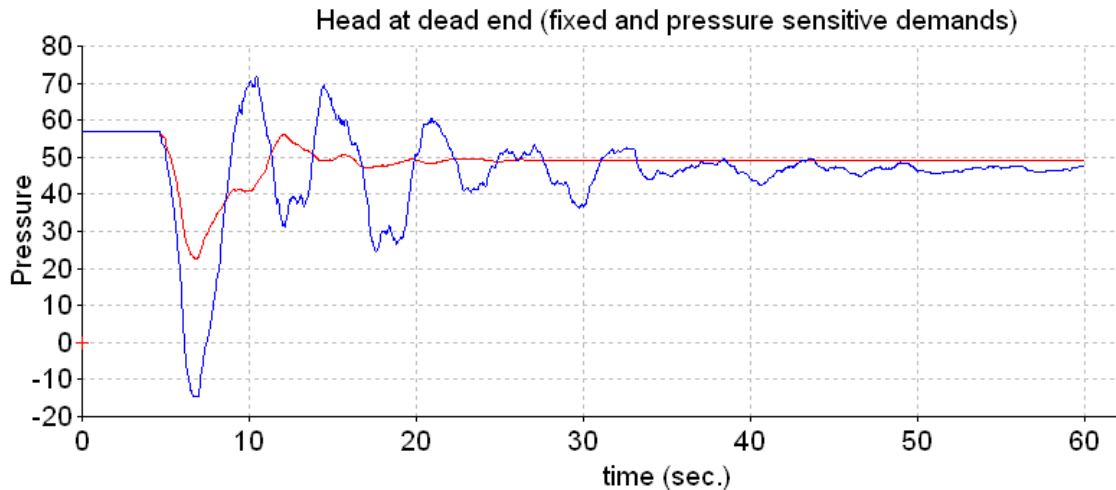
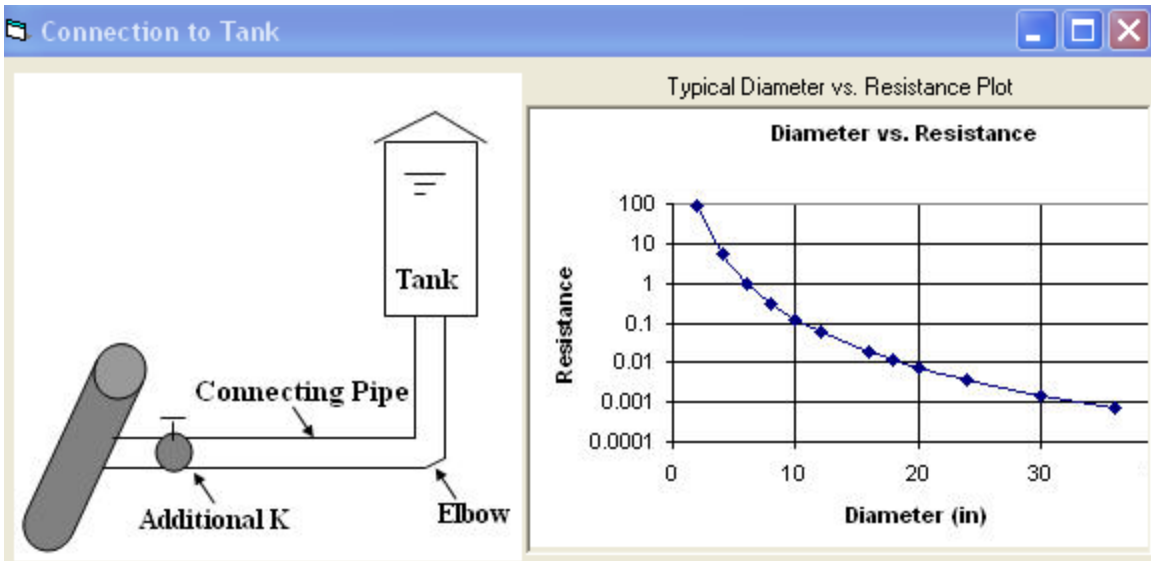


Figure CE2-17 Results With Fixed and Pressure Sensitive Demands – Surge1

Surge2 Setup (example surge compressor tank.p2k) – A compressor Surge Tank is added just downstream from the pump as shown in Figure CE2-18. This tank is operated such that 50 cubic feet of air is maintained under the initial conditions. The required data is shown in Figure CE2-18. The Tank Volume does not directly affect the surge analysis. The Inflow and Outflow Resistances will normally be the same and depend on the characteristics of the connection. A Surge tool is provided to calculate the resistance for a tank entrance and the use of this tool is illustrated in Figure CE2-19. The schematic and diagram shown in Figure CE2-19 indicate that a 6 inch connection resistance is approximately 1.0 and the actual calculations verify this value.

Node Type	Vert Closed Surge
Name	SDO-1
Elevation	95
Title	
On/Off	<input checked="" type="checkbox"/>
Inflow Resistance	1
Outflow Resistance	1
Tank Volume	100
Initial Gas Volume	50
Expansion Constant	1.2
Diameter	5
Initial Level	3
Hybrid	<input type="checkbox"/>

Figure CE2-18 Adding a Closed (Compressor) Surge Tank – Surge2



The figure shows a software window titled "Resistance Calculation Tool". It has a "Unit" dropdown menu set to "English". Below it is a "Calculate Resistance From" dropdown menu set to "Connection to Tank". There are several input fields: "No. of elbows" (1), "Pipe Diameter" (6 in), "Length of Pipe" (4 ft), "Additional k's" (1.5), and "Friction Factor(f)" (0.02). A "Compute Resistance" button is located below these fields. At the bottom, the result is displayed as "Resistance = 0.9720585698".

Figure CE2-19 Resistance Tool – Tank Entrance – Surge2

Surge2 Results - Figure CE2-20 compares the pressure plot at the dead end with and without the surge tank. For this comparison the Fixed Demand option is used.

Sizing Bladder Tank – The results of the analysis using a compressor vessel can be used to size and precharge a bladder tank which will provide the same response. A tool is provided to do this. Three data items are needed to use the tool: the initial air volume, the maximum air volume, and the initial head at the tank. The initial air volume was input so we know this value. A plot of air volume shown in Figure CE2-21 shows the maximum air volume is 71 cubic feet and the initial line head is calculated by the initial steady state analysis. This is shown in the Surge Report (Figure CE2-22).



Figure CE2-20 Results With and W/O Surge Tank (Fixed Demands) – Surge2

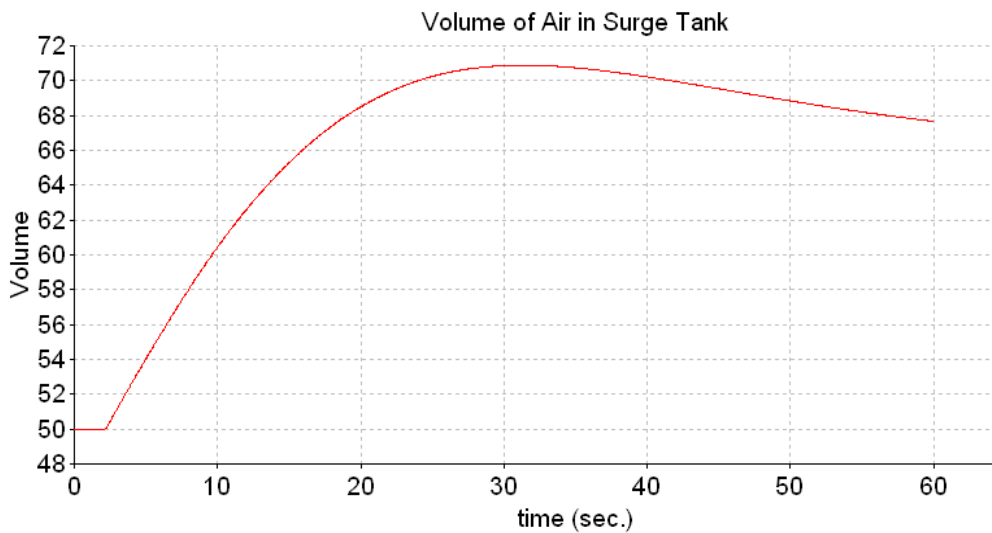


Figure CE2-21 Air Volume – Compressor Surge Tank – Surge2

SURGE PROTECTION DEVICE DATA

Pos. #1	Pos. #2	Ext. Pos.	Resistances (Diameter*)		Line Head	Initial Flow	- Surge Tank Data -	
			Out	In			Total_Vol	Ini_Gas_Vol
SDO-1		75	1.00	1.00	189.12	0.00	100.0	50.0

Figure CE2-22 Surge Results – Initial Head at Surge Tank– Surge2

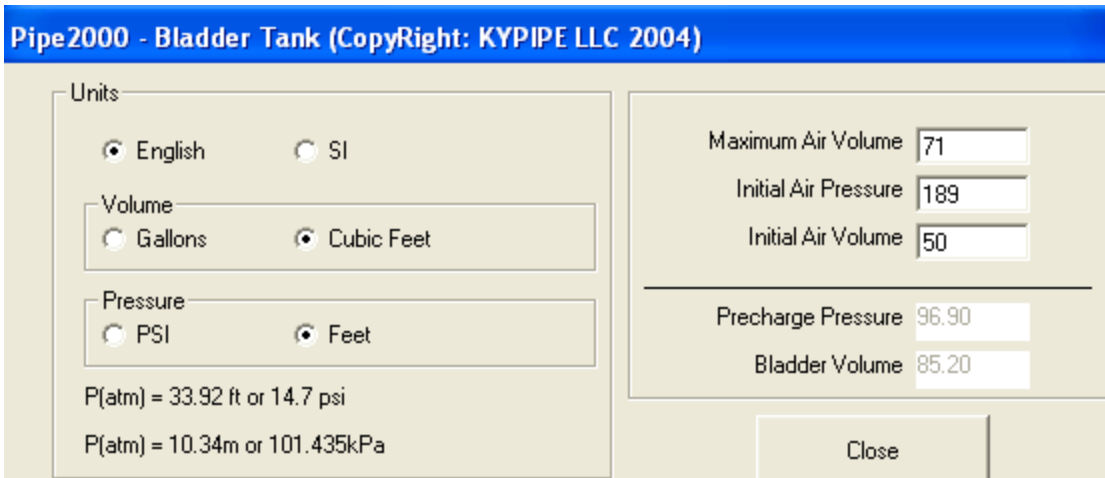


Figure CE2-23 Bladder Tank Size and Precharge Tool – Surge2

The Bladder Tank Tool shown in Figure CE2-23 calculates the size (85 cubic feet) and precharge (97 ft.) required for a Bladder Tank which will perform the same as the compressor vessel. This is easily confirmed by changing the closed surge tank to a bladder tank with the above characteristics.

Water Quality Exercises

WQ1 (Water Age in Tank 25%.P2K): This example illustrates the use of Pipe2018-EPANET program to compute water age at different locations in the distribution system. Assume that the tank is almost full at time 0 (say 259.7 ft) and that the tank level returns to the same level at the end of 24 hours after a 25% turnover (that is the tank level drops to about 250ft). Set up and run an EPS analysis to reflect this condition. This analysis requires a control switch on the pump and the required control switch setup is shown in Figure CE2-24. In addition, the pump speed setting should be changed to 0.976 in order to bring the tank level back to where it originally started. Figure CE2-25 shows the pump speed setting screen with the pump speed ratio set to 0.976.

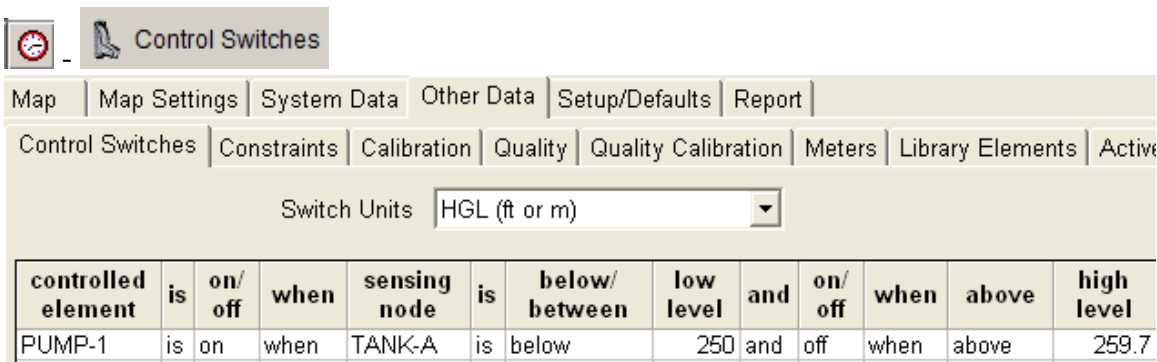


Figure CE2-24. Control Switch Setting for WQ1

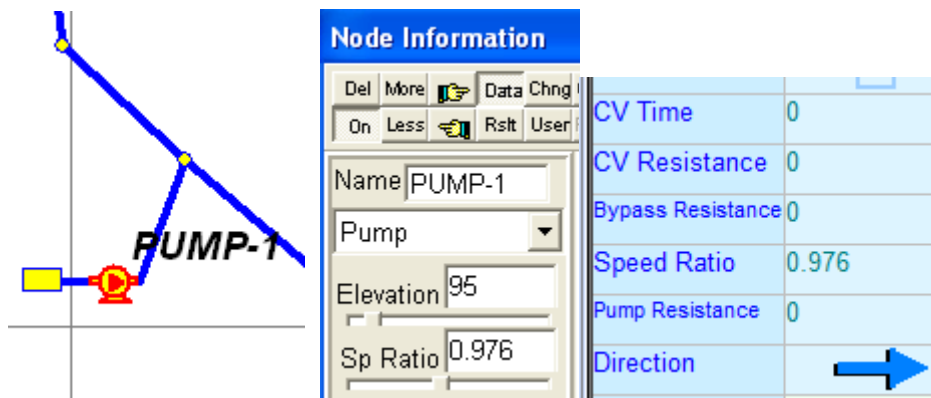


Figure CE2-25. Speed Ratio Setting for Pump-1 (for WQ1)

Once the model is set up to run with its tanks starting and ending at the same level during the specified time period (typically 24 hours), it can be used to compute water ages at different locations of the system. Access the water quality screen (-

or Other Data | Quality screen) and provide a total simulation time of 500 hours, a water quality computational time of 0.1 hours, age of 1 hour for the reservoir R-1. Figure CE2-26 shows the corresponding water quality data screens. Run the water quality analysis with an option to load results for the entire simulation period (500 hours) but load very 10th set of results (Figure CE2-27).



Figure CE2-26. Water Quality Data Screens for WQ1

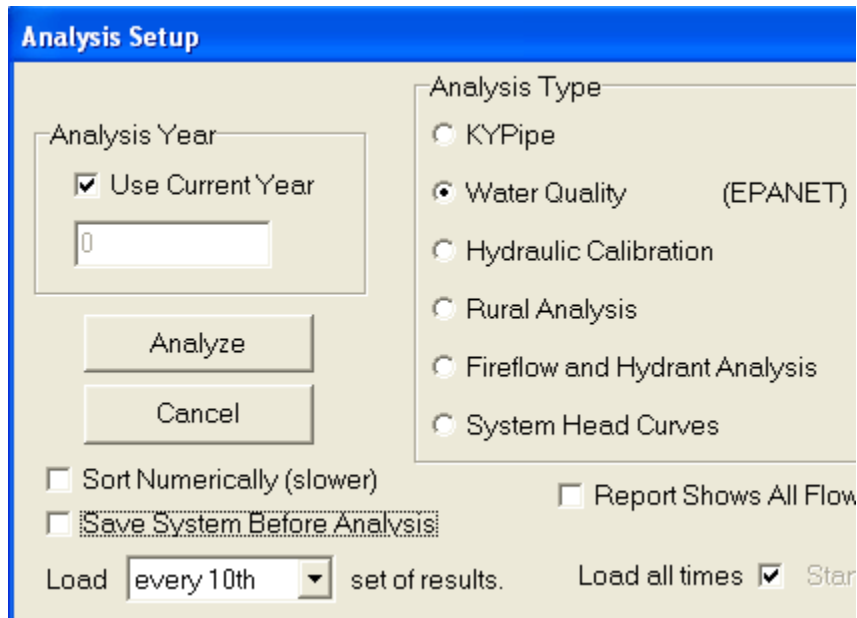


Figure CE2-27. Analysis Setup for WQ1

Figure CE2-28 shows the water age in TANK-A during the 500 hours simulation. As the tank was exercised only by about 25%, the net age of water continues to increase and eventually stabilize around 120hours.

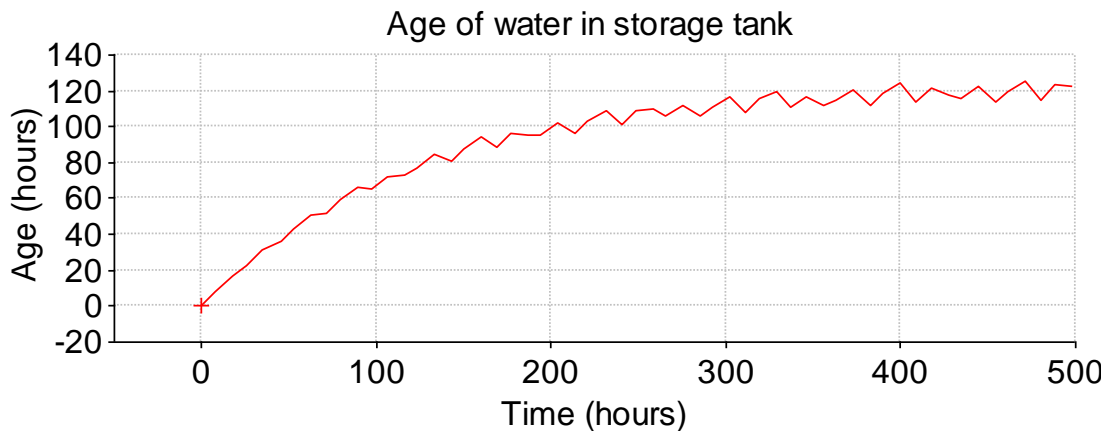


Figure CE2-28. Age of water in storage tank (WQ1)

WQ2 (Water Age in Tank 75%.P2K): This example is the continuation of the previous example illustrating the impact of about 75% turnover in tank level on the age of water in the tank. Figure CE2-29 and 30 illustrate the data screens for this analysis and Figure CE2-31 shows the water age graphs for TANK-A.

Control Switches												
Map Map Settings System Data Other Data Setup/Defaults Report												
Control Switches Constraints Calibration Quality Quality Calibration Meters Library Elements Active												
Switch Units: HGL (ft or m)												
controlled element	is	on/off	when	sensing node	is	below/between	low level	and	on/off	when	above	high level
PUMP-1	is	on	when	TANK-A	is	below	230	and	off	when	above	259.7

Figure CE2-29. Control Switch Setting for WQ2


Name: PUMP-1	ID: 1	CV Resistance: 0
Pump	Head	Bypass Resistance: 0
Elevation: 95	Flow	Speed Ratio: 1.01
Sp Ratio: 1.01	Eff%	Pump Resistance: 0
	200	Direction: 
	180	
	150	
	0	
	0	

Figure CE2-30. Speed Ratio Setting for Pump-1 (WQ2)

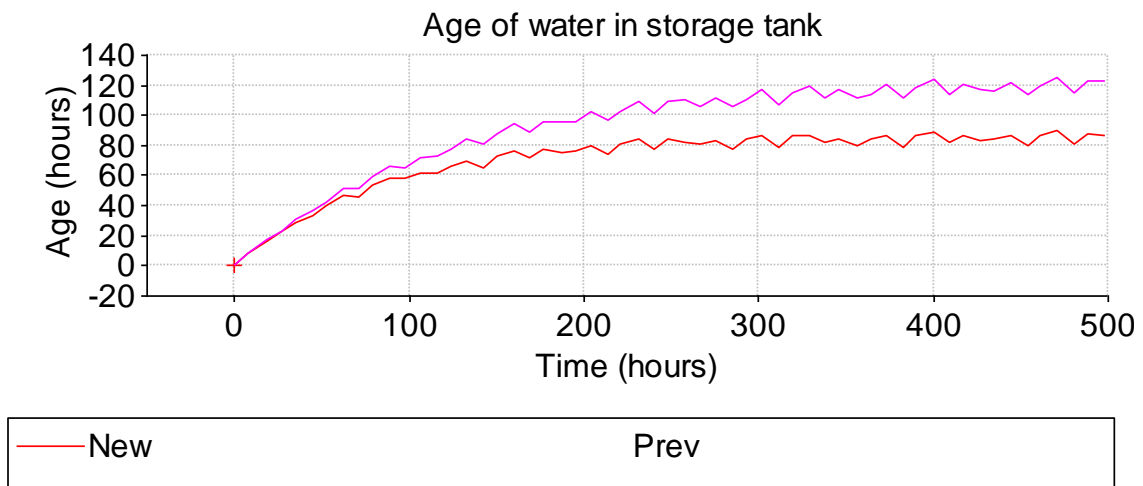


Figure CE2-31. Age of water in storage tank(WQ2)

WQ3 (Water Quality Chlorine.P2K): This example illustrates the computation of residual chlorine concentrations in the distribution system. Use **Water Quality Chlorine.P2K** model and provide necessary additional data as shown in various figures of this section to perform residual chlorine analysis. Use a wall reaction rate of -0.8/day and bulk reaction rate of -1.25ft/day and a first order decay rate for all reactions. Figure CE2-32 shows the water quality data screens along with the necessary data. An initial

concentration of 2mg/l (ppm) for the tank (TANK-A) and a concentration of 2.5mg/l for the reservoir (R-1) are assumed. Complete mixing of water is assumed for the tank and the data is specified by selecting the “Mixed” option for the mixing model.

Global Bulk Reaction Rate	-1.25	Quality Simulation Time	500	
Global Wall Reaction Rate	-0.8	Time Units	Hours	
Order of Reaction - Bulk	1	Quality Time Step	0.1	Update Tal
Order of Reaction - Wall	1	Quality Parameter	Chemical	
Order of Reaction - Tank	1	Chemical/Tank Name	Chlorine	
Limiting Potential	0	Attribute used for nodes "Initial Concentration"	Initial Conc	
Roughness Correlation	0	Attribute used for nodes "Initial Age"	Initial Age	
Quality Tolerance	0	Attribute used for pipes "Bulk Reaction Rate"	Bulk Rate	
Diffusivity (sqr ft/sec)	1.3E-8	Attribute used for pipes "Wall Reaction Rate"	Wall Rate	

Tank Source Data

Tank	Initial Concentration	Pattern	Bulk Reaction Rate	Mixing Model	Volume
TANK-A	2			Mixed	

Reservoir Source Data

Reservoir	Initial Concentration	Pattern
R-1	2.5	

Figure CE2-32. Water Quality Data Screens for WQ3

Figure CE2-33 shows the residual chlorine concentration at one of the tail end nodes (node 20) during the last 50 hours of the simulation.

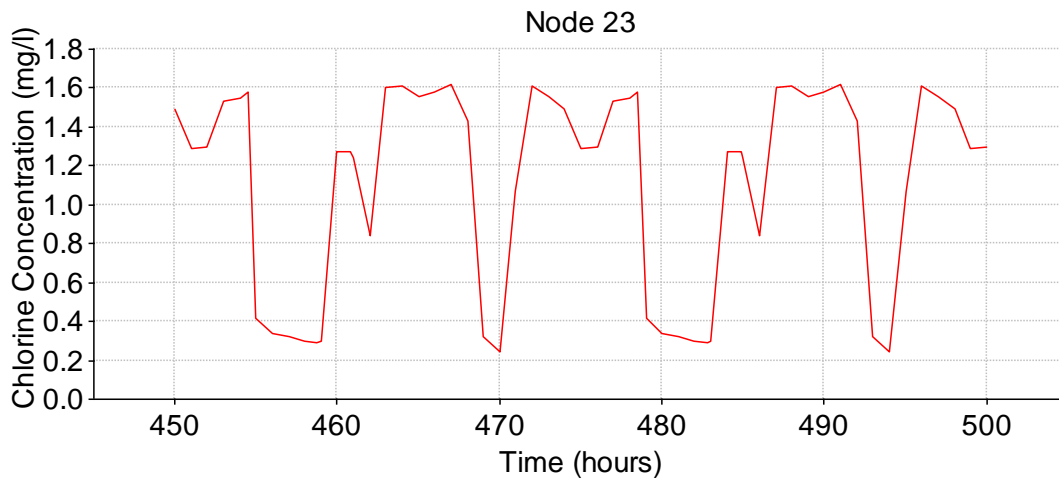


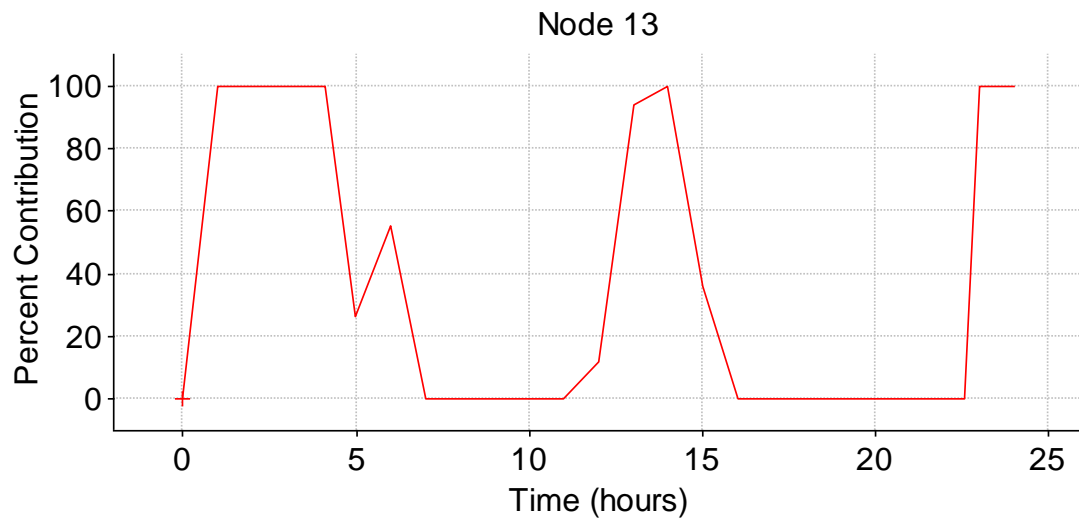
Figure CE2-33. Residual Chlorine Concentration at Node 23 (WQ3)

WQ4 (Water Quality Trace.P2K): This example illustrates tracing percent contribution of water from a specified source (tank or reservoir) to different part of the network. In this example, the percent contribution from TANK-A to different parts of the network are computed. Figure CE2-34 shows the water quality data screen for this example.

Quality Simulation Time	<input type="text" value="24"/>
Time Units	<input type="text" value="Hours"/>
Quality Time Step	<input type="text" value="0.1"/>
Quality Parameter	<input type="text" value="Trace"/>
Chemical/Tank Name	<input type="text" value="TANK-A"/>

Figure CE2-34. Water Quality Data Screen for WQ4

Figure CE2-35 shows the plot of percent contributions from TANK-A to node 13 over a 24-hour period.



Section 3 – Training Exercises

Training Exercise #1 – Industrial Water Distribution System

Description - (*Industrial Base.P2K*) the schematic shown below in Figure T1-1 represents a water distribution system for a large industry. It is fed from a large city water main. The pressure in the main will vary with the flow removed. A fire flow test on a nearby hydrant gave an 80 psig static pressure and a residual pressure of 69.6 psi at a flow of 3600 gpm. The water tower is for fire protection and the elevation of the connection is 100 feet. The line length, diameters, node elevations, and normal demands for the industry are shown on the schematic. Two valves are shown with data for the valve characteristics. Carry out the following steady state scenarios.

- 1. Prepare the model and data and analyze the system for the demands shown.
- 2. If the storage tank is full the valve leading to the tank will close thereby eliminating flow to the tank. Modify the data file created in part 1 to simulate altitude valve closure. You may accomplish this by
 - A. Closing one of the pipes leading to the tank
 - B. Closing the tank (use on/off button in the node information window)
 - C Closing the Globe Valve
 - C. Use “Node Changes” menu to close either of the elements – valve, pipe, or tank
- 3. Peak demands of 150% normal are expected. Analyze the system (with the globe valve open) for peak demands.
- 4. Change the diameter of the 680-foot line to 10” and analyze the system with normal and peak demands.
- 5. Repeat case 4 with the Butterfly Valve set to 50% open.
- 6. Use Change Data to set up the 6 cases described above.

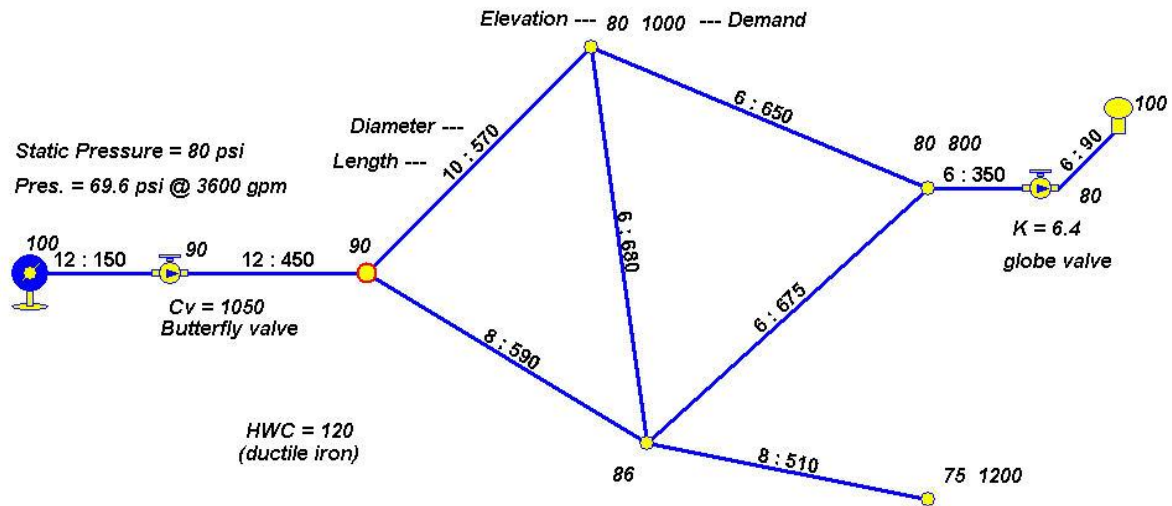
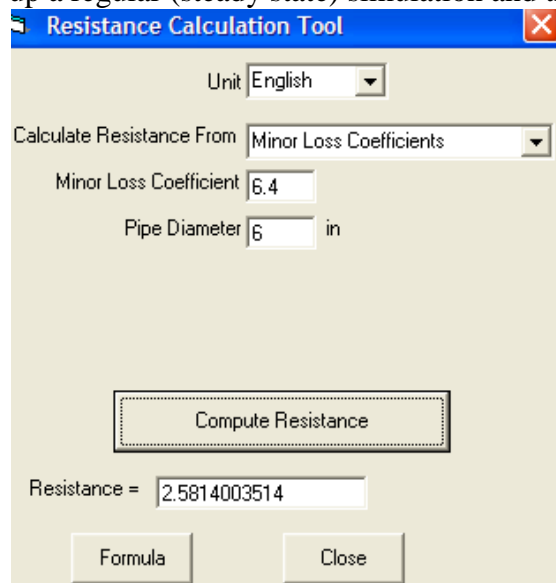


Figure T1-1 – Industrial Water Distribution System



Creating the Model -note that the network layout is presented as a “not to scale” schematic picture. Therefore the system can be laid out to represent the arrangement shown in Figure T1-1 but lengths will be entered and not scaled from the layout. The system contains two valves, a tank, and a connection to a supply with variable pressure (Variable Pressure Supply).

Model Data – The two valves require either a Resistance (R) or Valve Coefficient. A tool is available to use the data provided to determine the resistance for the 100% open valve. The use of this tool and the Data Boxes for the 2 valves, tank, and Pressure Supply are shown below. The data entry is straightforward. Note that the only additional data required for the tank is the Initial Level (250 feet). Max and min levels are not needed because we are setting up a regular (steady state) simulation and the level stays constant.




Resistance Calculator Tool, R for Globe Valve

Name	AV-2
Active Valve	
Elevation	80
R 100%	2.6
Init Ratio	1
Valve Type	Globe

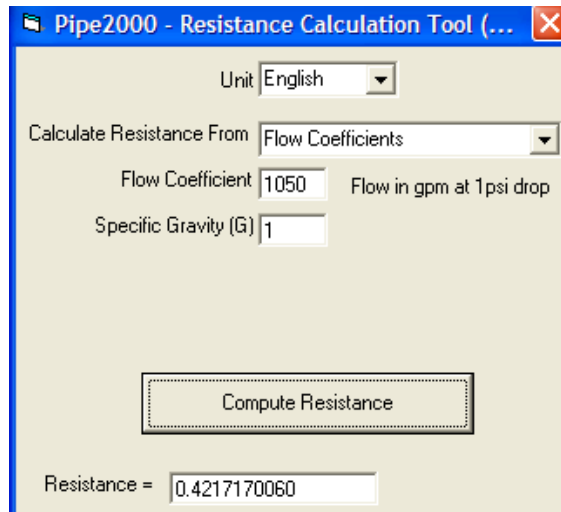
CV Resistance	0
Bypass Resistance	0
Grade	-----
Direction	
On/Off	
Resistance 100%	2.6
Initial Ratio	1
Valve Type	Globe

Active Valve Data

Name	TANK-B
Tank	
Elevation	100
Mx Level	0
Mn Level	0
Initial	250
Inflow	0

Node Type	Tank Variable Diam
Name	TANK-B
Elevation	250
Max Level	0
Min Level	0
Initial Level	250
Inflow	0
Volume.	1
Tank ID	1
Title	
On/Off	

Tank Data



Resistance Calculator Tool, R for Butterfly Valve

Cv Resistance	0
Bypass Resistance	0
Grade	-----
Direction	
On/Off	
Resistance 100%	0.42
Initial Ratio	1
Valve Type	Butterfly

Active Valve Data

Node Type	Rated Pressure Sup
Name	VP-1
Elevation	100
Title	
On/Off	
Ignore Changes	<input type="checkbox"/>
Gage Difference	0
Static Pressure	80
Residual Pressure	69.6
Residual Flow	3600

Pressure Supply Data

Figure T1-2 – Use of Tool and Node Data Boxes – Exercise T1

Training Exercise #1 – Regular Simulations

Regular Analysis Results (*Industrial Base.P2K*) – The baseline model was set up and two cases were run.

- 1) Case 1 – both valves fully opened
- 2) Case 2 – the globe valve is closed

The flowrates (gpm) and pressures (psi) for Cases 1 and 2 (globe valve closed) are shown in Figures T1-3 and T1-4.

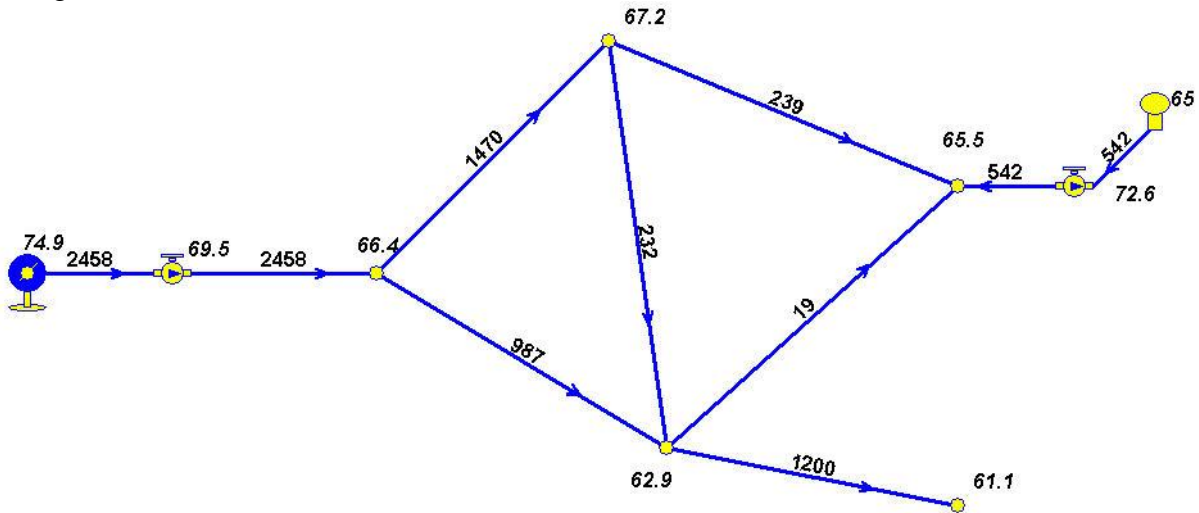


Figure T1-3 – Results Case T1-1

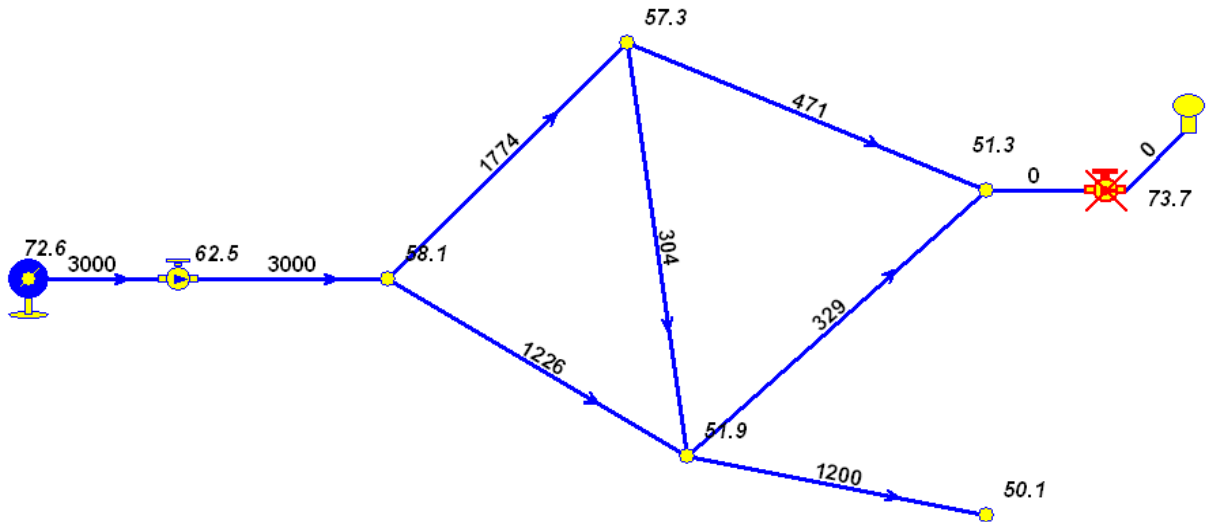



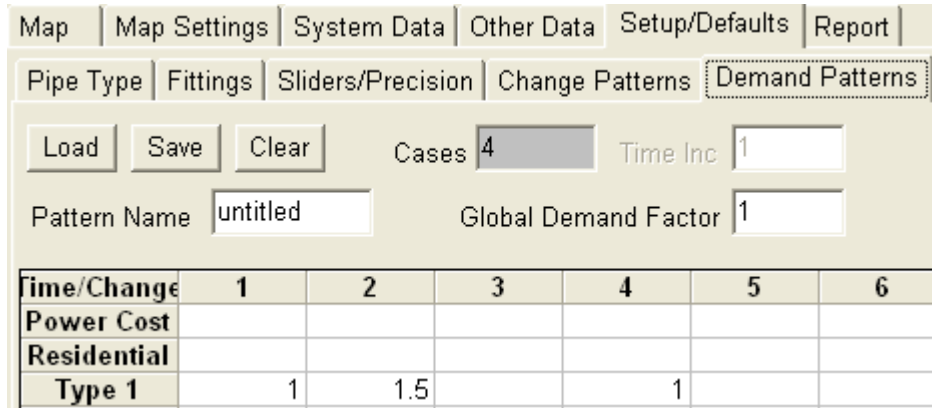
Figure T1-4 – Results Case T1-2 – Globe Valve Closed

Using Change Data (*Industrial Changes.P2K*) – For item 6 you are asked to prepare data for all 6 simulations using the “Node Changes” menu. Remember that except for system demands, the changes made for previous runs define the system characteristics prior to the next run and it might be necessary to include data to change the parameters back to their original values. The following cases are to be set up.

- Case 0** – Baseline data
- Case 1** – Same as 0 with globe valve closed
- Case 2** – Globe valve opened and Global Demand Factor (GDF) of 1.5
- Case 3** – Same as 2 with 680’ pipe (pipe 7) diameter = 10 inches (GDF = 1.5)
- Case 4** – Same as 3 with GDF = 1.0
- Case 5** – Same a 4 with butterfly valve setting = 0.5


These Changes require a Demand Pattern setup to define the GDF’s and several Change Data Boxes for the Node and Pipe Changes. These are shown below:

KYnetic Demands menu icon: 



Time/Change	1	2	3	4	5	6
Power Cost						
Residential						
Type 1	1	1.5			1	

Figure T1-5 – Demand Pattern - Case T1-Changes

Note the Demand Pattern is accessed with  or **Setup/Defaults/Demand Pattern** and entries left blank apply the last factor to the Demand. Also for this example all demands are Type 1. The 3 Change Data boxes required for this analysis are shown below. Note that the diameter change for the pipe applies to subsequent cases unless a new value is specified.

Node Changes			
Cut	Copy	Paste	Clear
Time/Case		Value	
5	R 0.5		

Changes for AV-1		
Case	Change	Value
5	Ratio	0.5

Case 5 - Butterfly Valve

Node Changes			
Cut	Copy	Paste	Clear
Time/Case		Value	
1	R 0		
2	R 1		

Changes for AV-2		
Case	Change	Value
1	Ratio	0.5
2	Ratio	0

Case 1 and 2 – Globe Valve

Pipe Changes			
Cut	Copy	Paste	Clear
Time/Case		Value	
3	D 10		

Changes for 7		
Case	Change	Value
3	Diameter	10

Case 5 – 680 ft. pipe

Figure T1-6 – Change Data - Case T1-R6 – Exercise T1

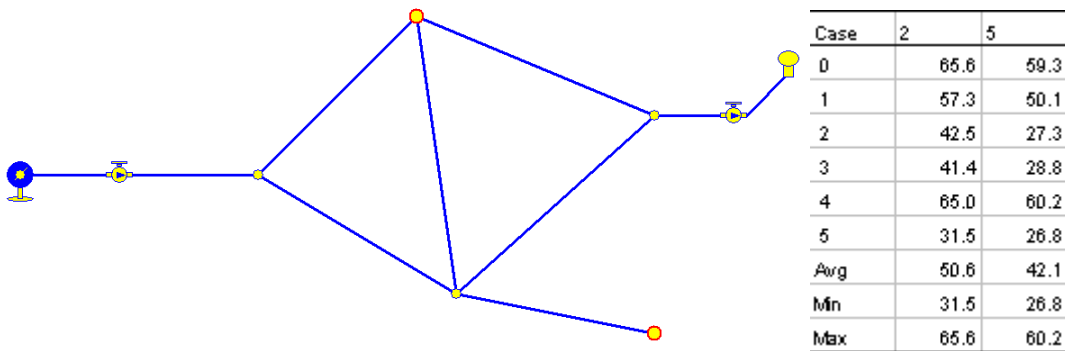


Figure T1-7 – Results for Multiple Simulations (Table) - Cases 0-5 – Exercise T1

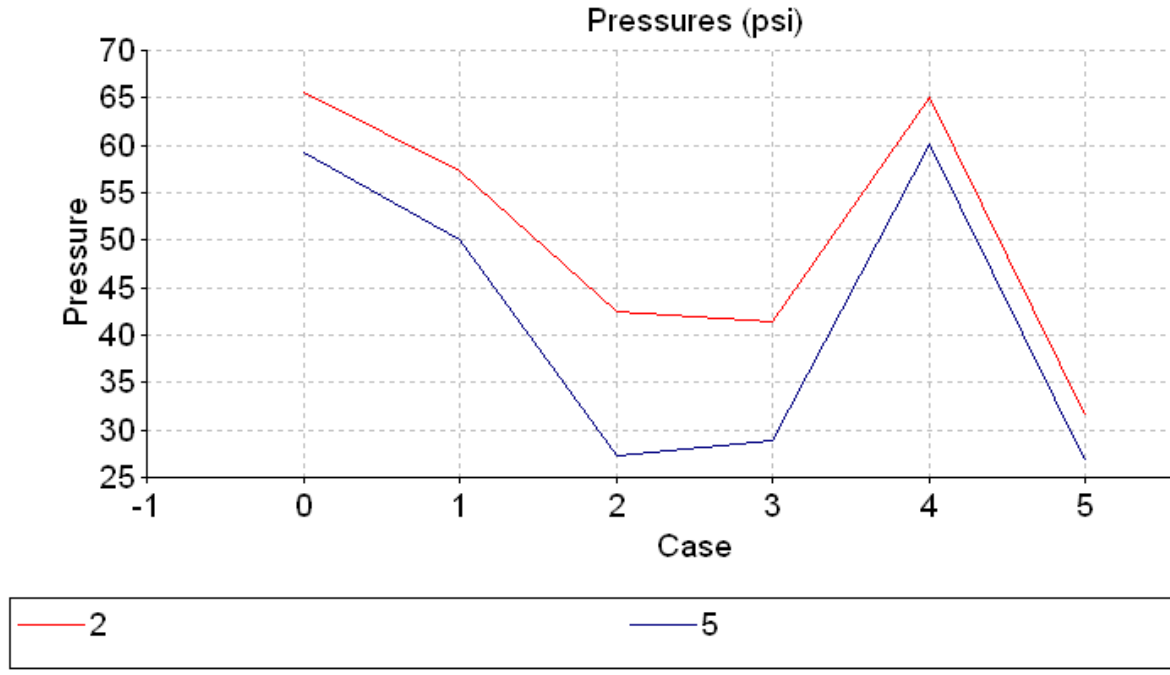


Figure T1-8 – Results for Multiple Simulations (Plot) - Case 0-5 – Exercise T1

Results for Multiple Simulations (*Industrial Changes.P2K*) – One advantage of setting up multiple simulations instead of several single case runs is that the results can be presented in a single table or plot as shown above for this exercise. Pressures for the two selected nodes are presented in a table (Figure T1-7) and plot (Figure T1-8) as shown.

Training Exercise #1 – Extended Period Simulations (EPS)

(*Industrial EPS1.P2K*) The schematic shown in Figure T1-1 represents a water distribution system for a large industry. It is fed from a large water main and the pressure in the main will vary based on the supply data provided. The water tower is for fire protection. Normal demands for the industry are shown on the schematic. The tank has the following characteristics:

Tank Details: Overflow elevation = 220ft, minimum elevation = 180ft, tank diameter = 30ft.

Setup and carry out the following EPS runs:

EPS1 (*Industrial EPS1.P2K*) - A 24-hour EPS using 1-hour computational intervals for the following demand multiplication factors, assuming that the tank is initially half full at 200ft.

- 0-8 hours, factor = 1

- 8-16 hours, factor = 1.5
- 16-24 hours, factor = 0.5

EPS2 (Industrial EPS2.P2K) - Add a 70 (useful) horsepower booster pump parallel to line 1. This pump will turn on when the water level in the tank drops below 190ft and will remain on until the water level exceeds 210ft. When the pump is off the pressurized supply directly feeds the system. Assume the booster **pump is initially off** with the water level in the tank at 200ft. Carry out a 24-hour simulation using a 1-hour computational interval with the same demand pattern as above.

EPS Data – To convert from a Regular Simulation to an EPS it is only necessary to access the EPS Data (🛑 or **System Data/EPS**) and provide the Total Time and Computational Time Period. In addition the Tanks must include a Maximum, Minimum level (in addition to Initial Level) and either a Diameter or Volume and a volume/depth table. Although not required, a Demand Pattern will often be needed to define changes in demands over the simulation. This data for Exercise T1 is shown in Figure T1-8.

If a Control Switch is needed to control pump or valve operation such as for EPS2 then additional data such as that shown in Figure T1-11 is required. To accomplish the desired control a pipe with the pump must be added as shown in Figure T1-11 to model the action when the pump is on. When the pump is on the valve will be closed and vice versa.

EPS Results (Industrial EPS1.P2K, Industrial EPS2.P2K) – Results are shown in Figures T1-9 and T1-10 for EPS1 when no booster pump is utilized. For this case the tank completely empties after 11 hours resulting in very low pressures. With a booster pump turned on by a control switch the tank does not empty pressures do not get as low. Figures T1-12 and T1-13 show these results.

Name	TANK-B	Node Type	Tank Fixed Diameter
Tank		Name	TANK-B
Elevation	100	Elevation	100
Mx Level	220	Max Level	220
Mn Level	180	Min Level	180
Initial	200	Initial Level	200
Inflow	0	Inflow	0
		Title	
		Diameter	30

Tank Data

Simulation Specs | Other | **EPS** | Reports


Use EPS

Total Time (hrs)


Computational Period (hrs)

Report Period (hrs)

Default Power Cost (\$/kwhr)

 Intermediate Reports

EPS Input



Time/Change	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Power Cost																	
Residential																	
Type 1		1							1.5								0.5
Type 2																	

Demand Pattern

Figure T1-9 – EPS Data – Exercise T1-EPS

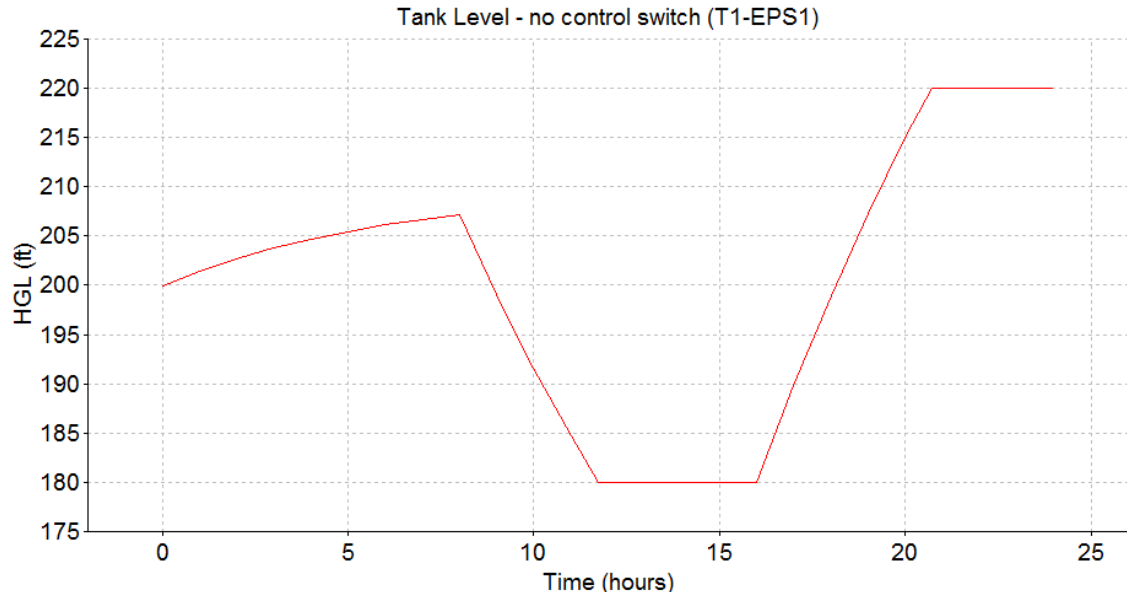


Figure T9 – EPS Results – Exercise T1-EPS1

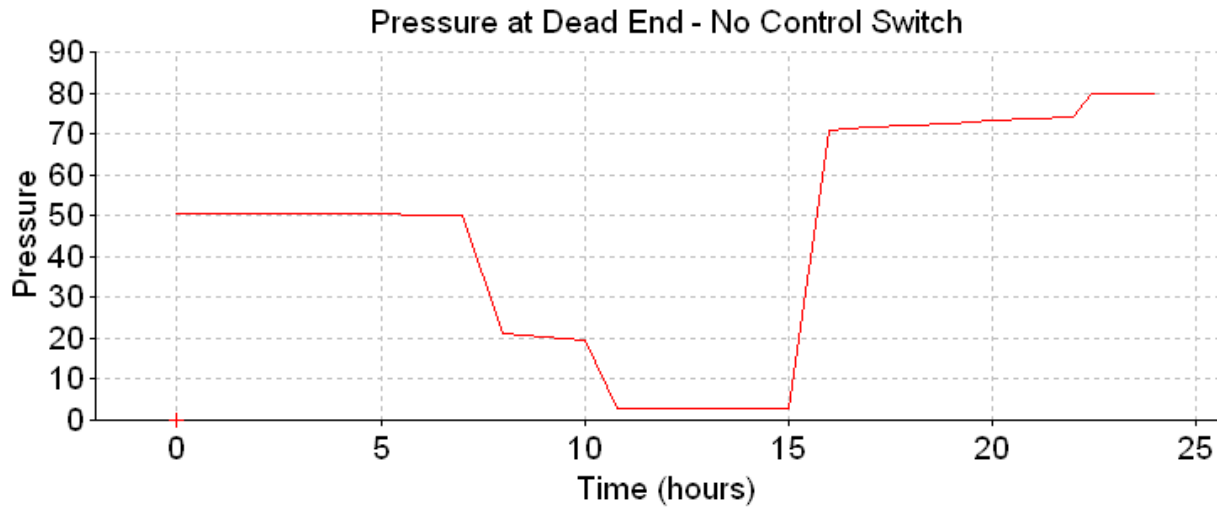
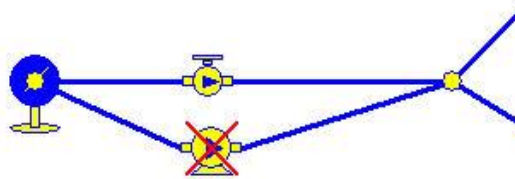


Figure T1-10 – EPS Results – Exercise T1-EPS1



Control Switches

Control Switches | Constraints | Calibration | Quality | Quality Calibration | Meters | Library Elements | Active

Switch Units: HGL (ft or m)

controlled element	is	on/off	when	sensing node	is	below/between	low level	and	on/off	when	above	high level
Pump-1	is	on	when	Tank-B	is	below	190	and	off	when	above	210
AV-1	is	off	when	Tank-B	is	below	190	and	on	when	above	210

Figure T1-11 Control Switch Model (pump initially off) and Data – T1-EPS2

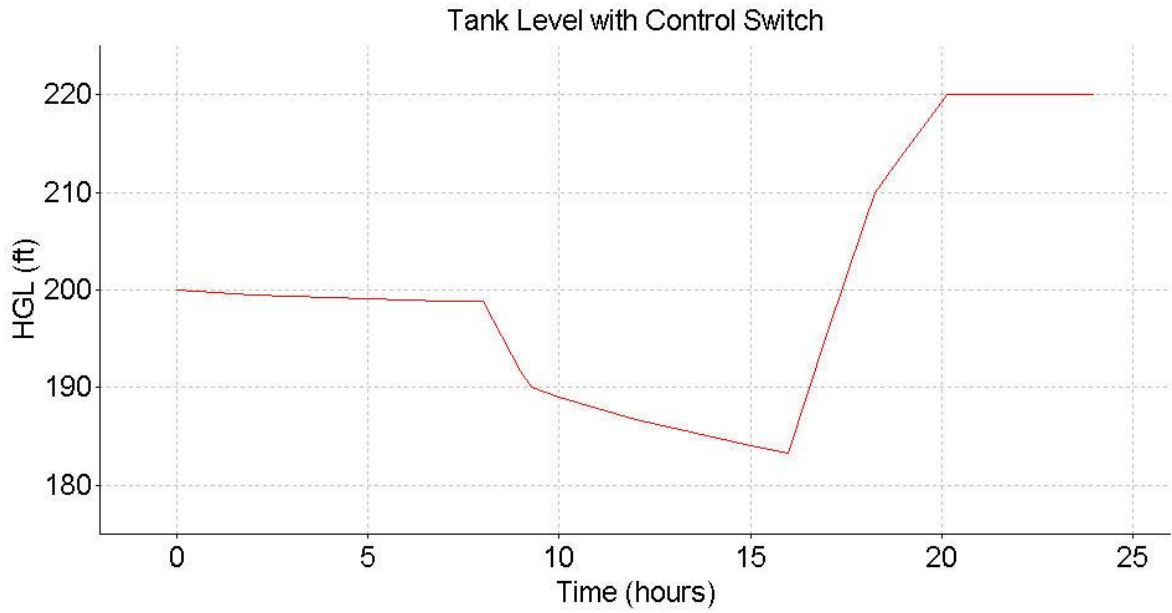


Figure T1-12 – EPS Results – Exercise T1-EPS2

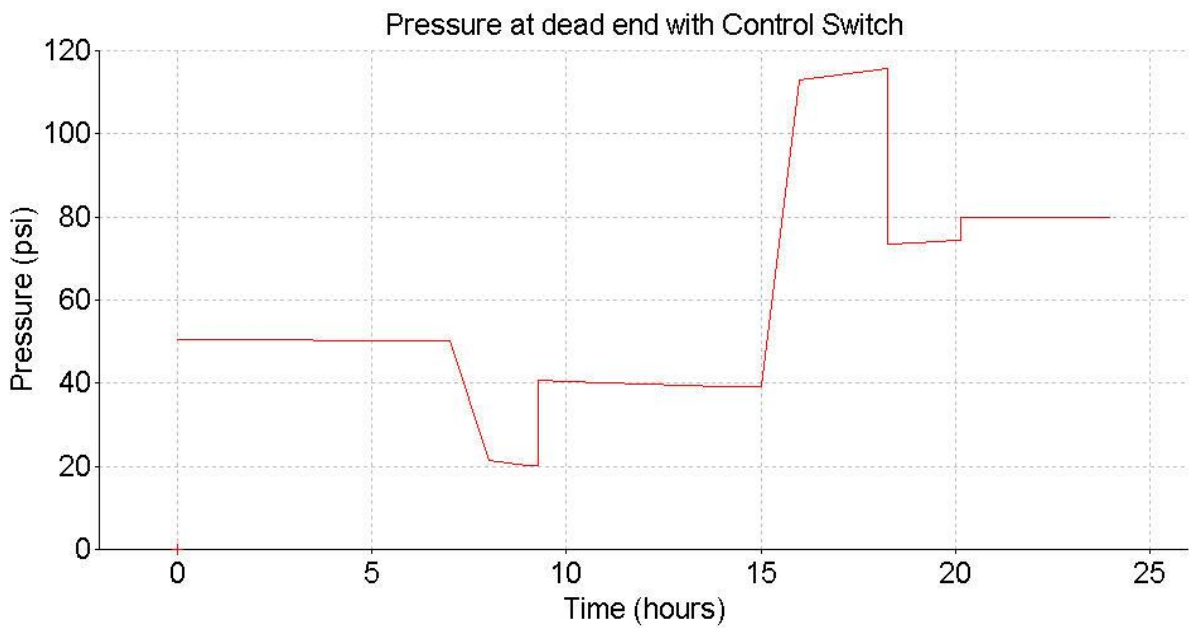


Figure T1-13 – EPS Results – Exercise T1-EPS2

Training Exercise #1 – Surge Analysis (Industrial Surge.p2k)

1) Surge Analysis - Modulating Regulating Valves – Training Exercise #1

Problem description (*Industrial Surge.P2K*) - Set up and carry out a 30-second surge analysis to determine the pressure increase due to a rapid (2-second) rejection of the 1200 gpm discharge. The principal additional data required is the wave speed in the pipes and a description of the cause of the transient.

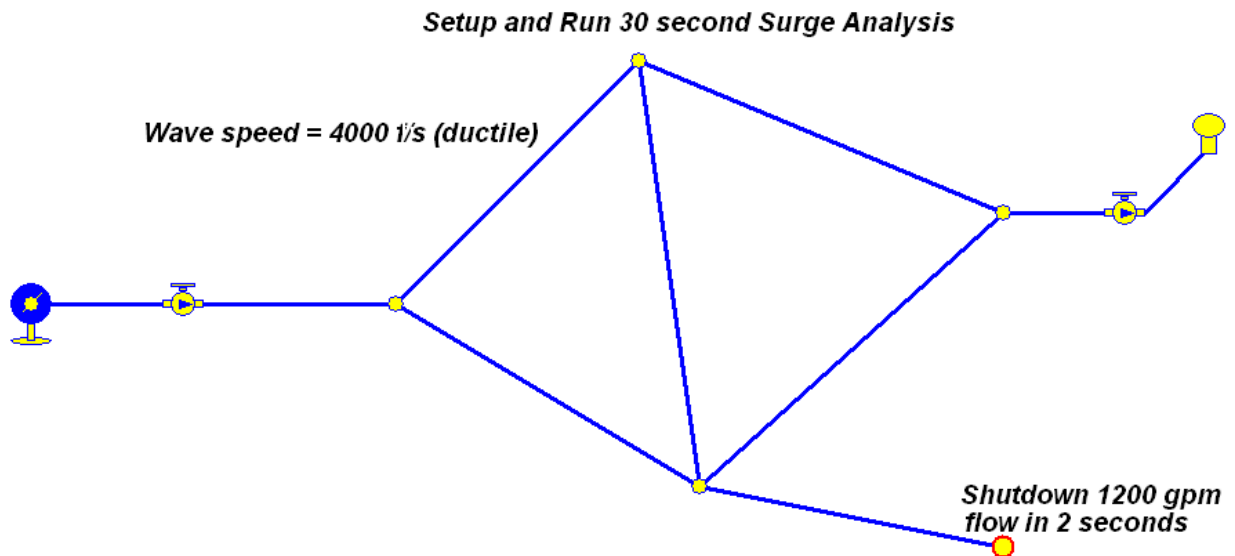


Figure T1-14 – Surge Analysis Conditions – Exercise T1-Surge

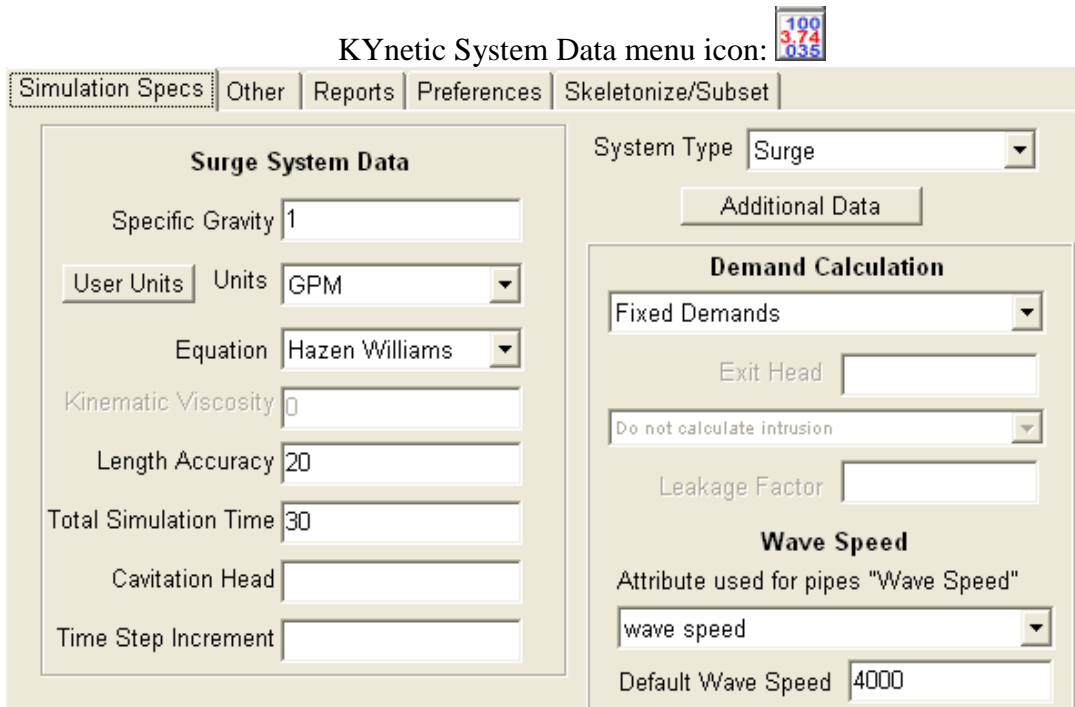



Figure T1-15 – Surge System Data – Exercise T1-Surge

Surge Model Setup - Figure T1-15 shows the  or System Data/Simulation Specifications screen for this surge analysis. To go from the baseline data model to the surge model simply select **Surge** from the System Type dropdown list (you must have a licensed copy of Surge) and enter the appropriate data. For most applications a Default Wave Speed can be used for most or all pipes. For this example 4000 ft/sec. is used based on the pipe material (ductile iron) and this value is acceptable for all the pipes and individual values need not be entered. The value used for wave speed will appear in the Pipe Data as shown in Figure T1-16. Pipe2018 includes a tool to help you calculate the wave speed and the result is close to 4000 ft/sec. The Total Simulation Time will depend on the pipe lengths and must be determined by the user. The Length Accuracy defines the maximum possible difference between model and actual pipe lengths and is typically 10 to 100 feet.

The cause of the transient is a 2-second shutdown of the 1200 gpm flow exiting the dead end. This type of transient occurs normally as the result of a valve closure. However, it is not necessary to install a valve to analyze the transient. Surge has the capability to model a specified demand change. This is set up using Change Data as shown in Figure T1-16. When a surge analysis is run using Surge a pressure trace is generated as the solution progresses. It is not necessary to set up this plot but it is a useful feature. The setup is shown in Figure T1-16, Node 5 is the dead end (it may be named differently in your model). The limits (Min and Max) should be set by the user based on the anticipated pressure range.

Name	5
Pipe Type	diameter 6
Wave Speed	4000
Length	675
Roughness	120
Fittings	
First Node	4
Last Node	3
Residential Meters	0
Install Year	0

Pipe Data with Wave Speed

Time/Case	Value
0	d 1200
2	d 1200
4	d 0

Time	Change	Value
0	demand	1200
2	demand	1200
4	demand	0

Demand Changes

Screen Plot Data

Use Selected Node

Node 5

Inlet

Min Head -50

Max Head 500

Title pm shutdown

Screen Plot Setup

Figure T1-16 – Surge Data Screens– Exercise T1-Surge

Results

The results for the pressure at the dead end node are shown in Figure T1-17. This shows that a maximum pressure of nearly 160 psi occurs due to the flow rejection. It should be noted that this transient is caused by a uniform change in the demand from 1200 gpm to 0 over 2 seconds. A valve closure will produce a transient based on the characteristics of the valve and will be different for each valve and different from the result shown in Figure T1-17.

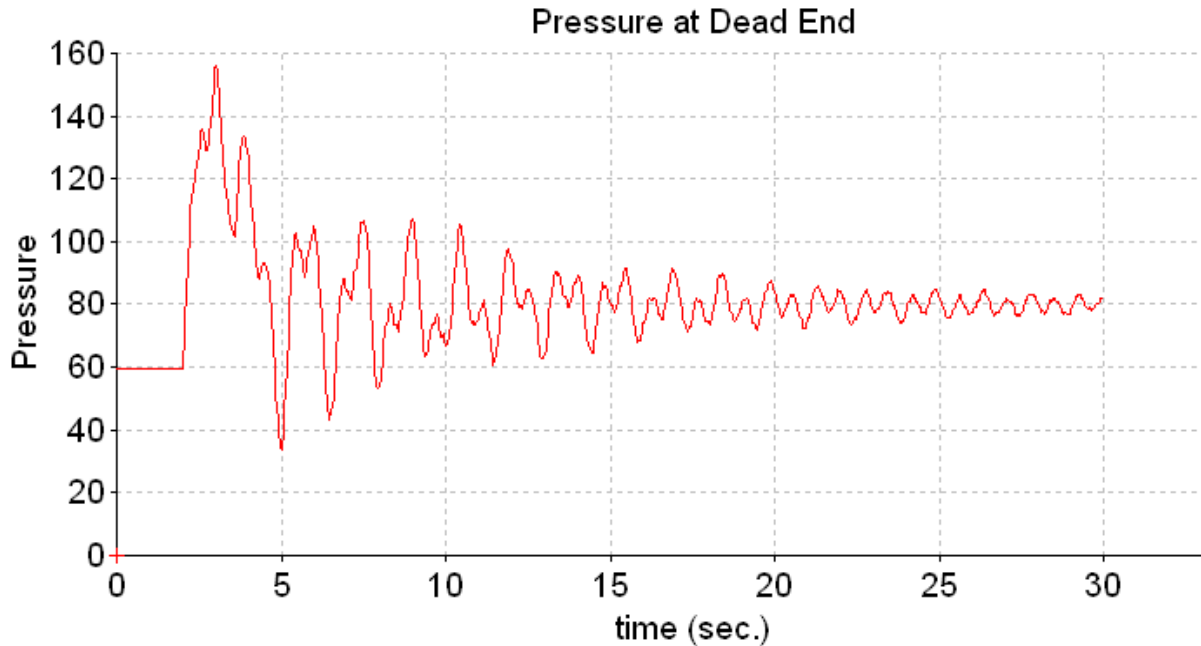


Figure T1-17 – Surge Analysis Result– Exercise T1-Surge

Using the Surge Option for Cavitation Calculations

The surge analysis is repeated for a more rapid shutdown (0.5 seconds) and the results are shown in Figure T1-17a. The faster shutdown produces a much more severe surge with pressure spikes in excess of 350 psi and extensive cavitation. This response is caused by the fact that the shutdown is completed before sufficient negative wave reflections have time to travel back to the source of the disturbance (dead end).

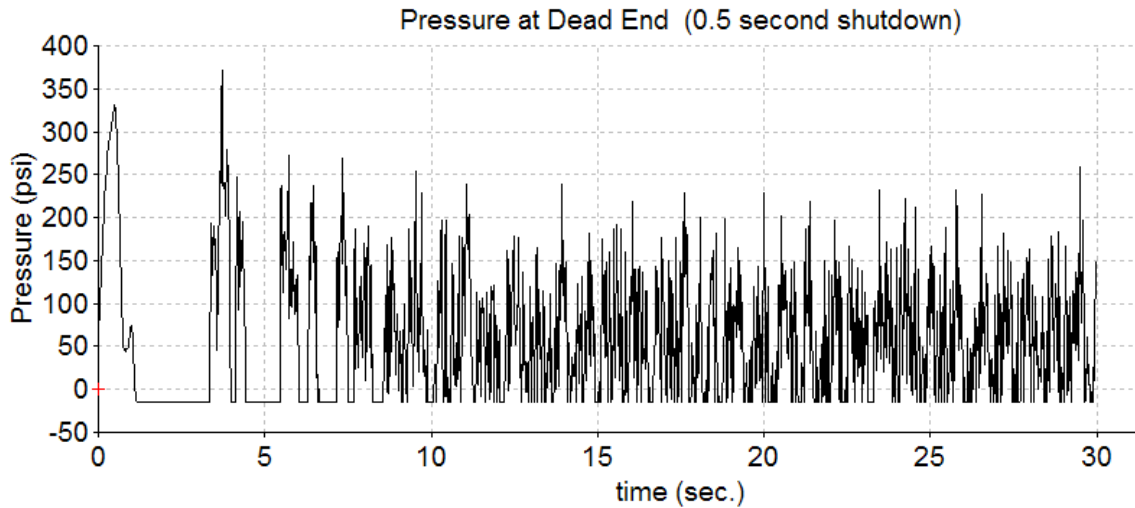


Figure T1-17a Pressure at Dead End – 0.5 second shutdown

The above example illustrates a typical transient calculation for the effects of cavity formation and collapse. Cavity collapse causes pressure spikes which are reflected negatively from reservoirs and other components and cause additional cavity formation and collapse and a severe response as depicted in Figure T1-17a. Transient flow models tend to predict the very worst response for this situation. In reality vapor cavity formation and collapse will release gasses which will soften the response. Surge provides a technique to model this softening of the effect of cavity collapse and the formation of pressure spikes. To do this the user can enter a number which represents the number of computational time intervals over which the collapse occurs. This data is accessed under

100
3.74
0.35

 or System Data | Simulation Specifications using the Additional Data/Demand Data button as shown in Figure T1-17b.

For this analysis the transient was calculated using a input of 20 time steps to soften the effects of cavity collapse. The results are shown in Figure T1-17c. This response is much more representative of measured responses where the cavitation tends to die out after several cycles of cavity formation and collapse.

100
3.74
0.35

Map	Map Settings	System Data	Other Data	Setup/Defaults	Report
Simulation Specs					
Surge System Data			System Type <input type="text" value="Surge"/>		
Specific Gravity <input type="text" value="1"/>			<input type="button" value="Demand Data"/>		
User Units <input type="text" value="GPM"/>			Additional Data		
Equation <input type="text" value="Hazen Williams"/>					
Kinematic Viscosity <input type="text" value="0"/>					
Length Accuracy <input type="text" value="20"/>					
Total Simulation Time <input type="text" value="30"/>					
Cavitation Head <input type="text"/>					
Time Step Increment <input type="text"/>					
Optional Stabilization Settings					
CV Setting for Inertial Effects <input type="text"/>					
Time Steps for Cavity Collapse <input type="text" value="20"/>					

Figure T1– 17b Surge System Data to set Cavity Collapse Time Steps

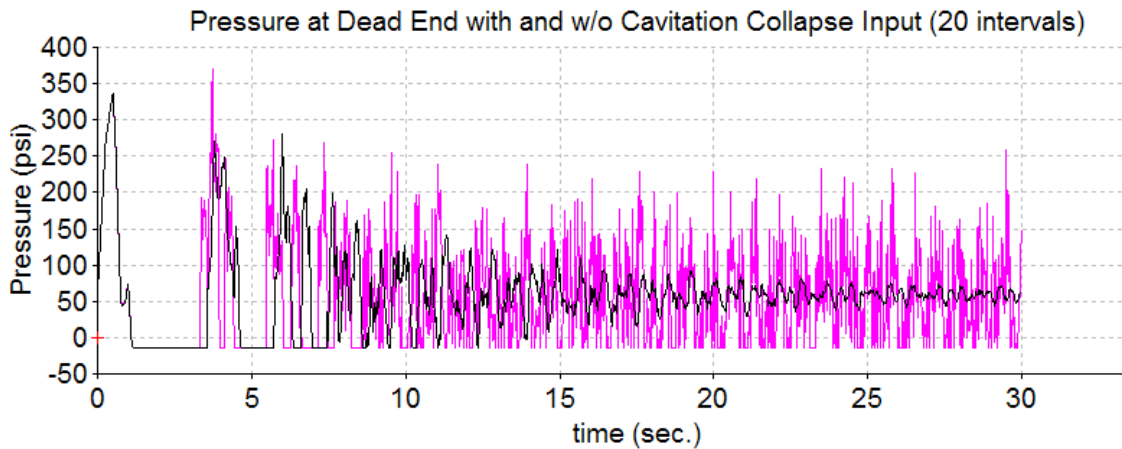


Figure T1–17c Pressure at Dead End – 0.5 second shutdown with and w/o Cavity Control Data (20 time steps for Cavity Collapse)

2) Surge Analysis - Modulating Regulating Valves – Training Exercise #1

This example exercise shown in Figure T1-18 is used to illustrate several methods which are available to handle regulators for surge analysis. This exercise calculates the transient caused by a 2-second ramp down of the demand at the dead end line from 1200 gpm to 0 gpm. A PRV set to 30 psi is positioned as shown in the supply pipe. Three options are available for modeling the PRV:

- 1) The regulator is handled as a constant resistance valve with the resistance based on the initial conditions at the valve (flow and pressure drop)
- 2) The regulator is handled as a modulating active valve (AV) with the initial and final settings based on the initial and final conditions for the regulator (flow and pressure drop)
- 3) A Modulating Regulator is modeled such that the regulator (RV) automatically modulates to hold the setting. The user specifies a time required to modulate by the amount of the initial setting which sets the response time.

For option 1 and 2 the conditions for the regulator are determined by running the steady state analysis for the initial condition (1200 gpm demand at dead end) and final condition (0 gpm demand at dead end) and looking at the RV report in the tabulated results. These give the following conditions for the PRV:

VALVE NAME	VALVE TYPE	VALVE SETTING (psi or gpm)	SETTING	UPSTREAM (psi)	DOWNSTREAM (psi)	THROUGH (gpm)
RV-1	PRV-1	30.00	ACTIVATED	77.67	30.00	2050.51
RV-1	PRV-1	30.00	ACTIVATED	82.95	30.00	896.21

Based on these results the fixed resistance for the valve can be computed from the initial condition as 5.28. Figure T1-19 shows the pressure transient at the dead end with no modulation of the valve setting.

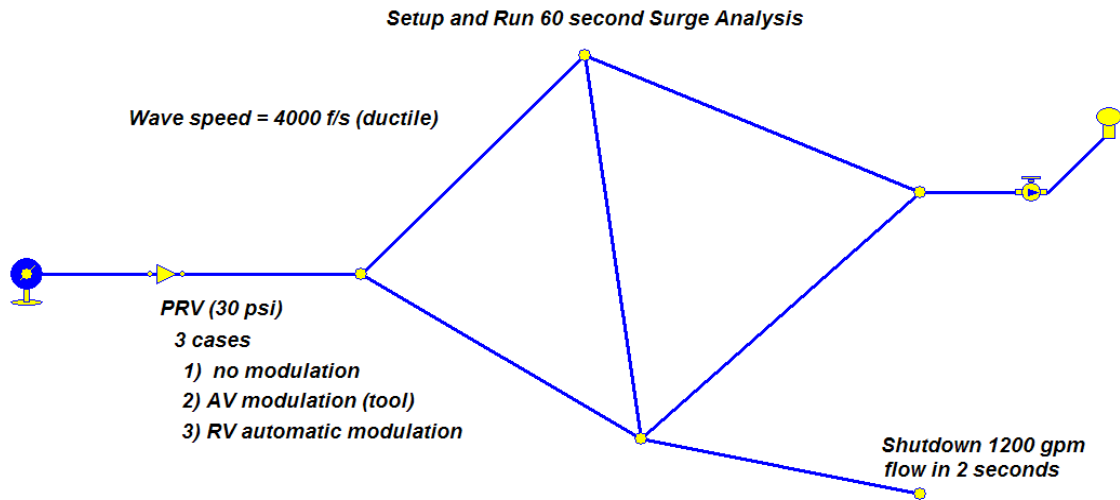


Figure T1-18 Training Exercise #1 - PRV set at 30 psi in Supply Line

The second option employs the Modulating Valve Tool as shown in Figure T1-20 to compute the settings for an Active Valve which modulates from the correct initial setting to the correct final setting. The user specifies the time period over which the modulation occurs and Figures T1-21 & 22 show results for 2 and 40 second response times.

The use of the Surge Modulating Valve option is illustrated in Figures T1-23 and 24. Figure T1-24 compares the results with and without modulation of the RV. The response time for modulation is set to 2 seconds. Which means the modulation will occur fairly rapidly. It can be seen that this approach provides results very similar to option 2.

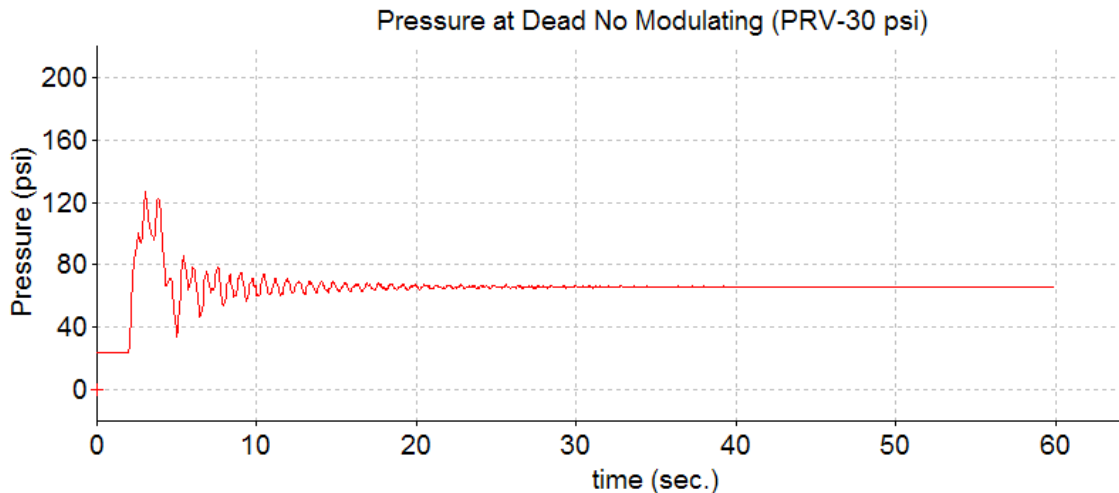


Figure T1–19 Pressure at Dead End – no RV Modulation (constant resist.)

Units
 English SI Head Pressure

Sp. Gravity = Flowrate

Wide Open Resistance Flow Coefficient

Initial Steady State Conditions
 Upstream Pressure psi
 Downstream Pressure psi
 Flowrate

Final Steady State Conditions
 Upstream Pressure psi
 Downstream Pressure psi
 Flowrate

Resistance = Headloss / {Flow²}, where Headloss is in feet or meters and Flow is in cubic feet per second or cubic meters per second

Flow Coefficient = Flow (in gpm or m³/hr) that develops a pressure drop of 1 psi or 1 bar across the valve

Modulation Settings
 Wide-open Resistance
 Initial Ratio
 Final Ratio

Figure T1–20 RV Modulation Tool to Compute AV Settings

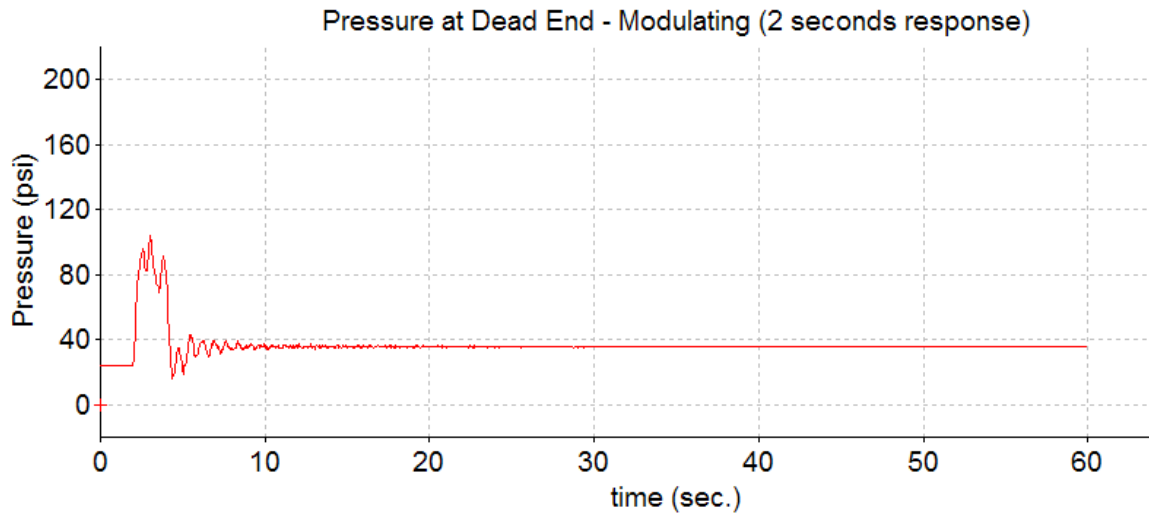


Figure T1-21 Pressure at Dead End – AV Modulation Tool (2 sec.)

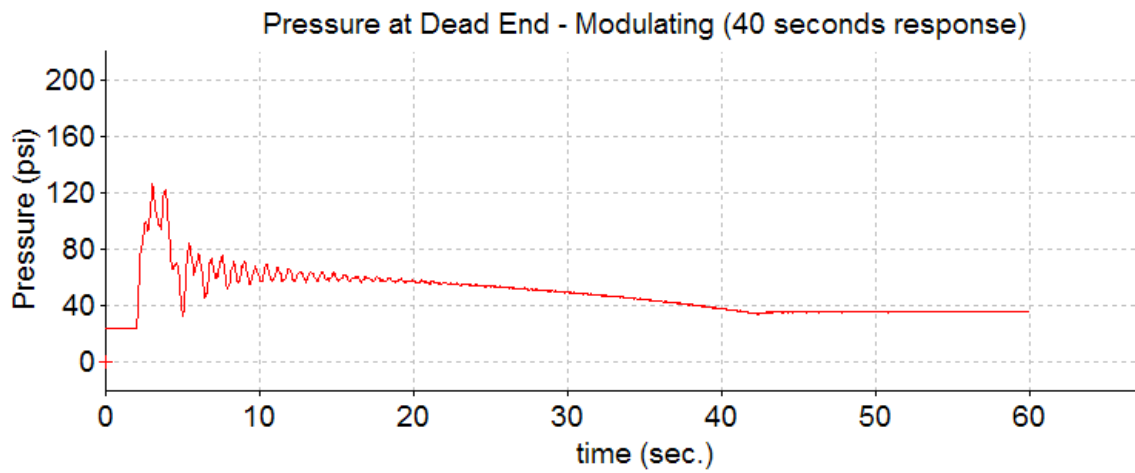


Figure T1-22 Pressure at Dead End – AV Modulation (40 sec.)

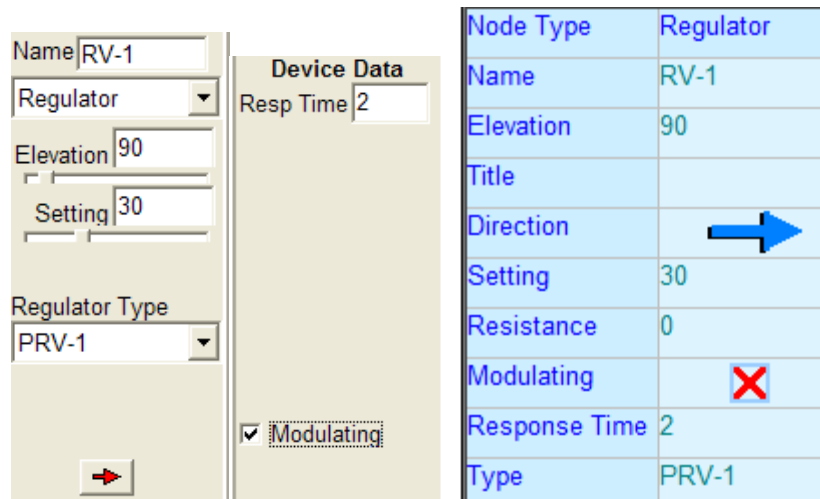


Figure T1–23 Menu Boxes for Modulating RV (PRV set at 30 psi)

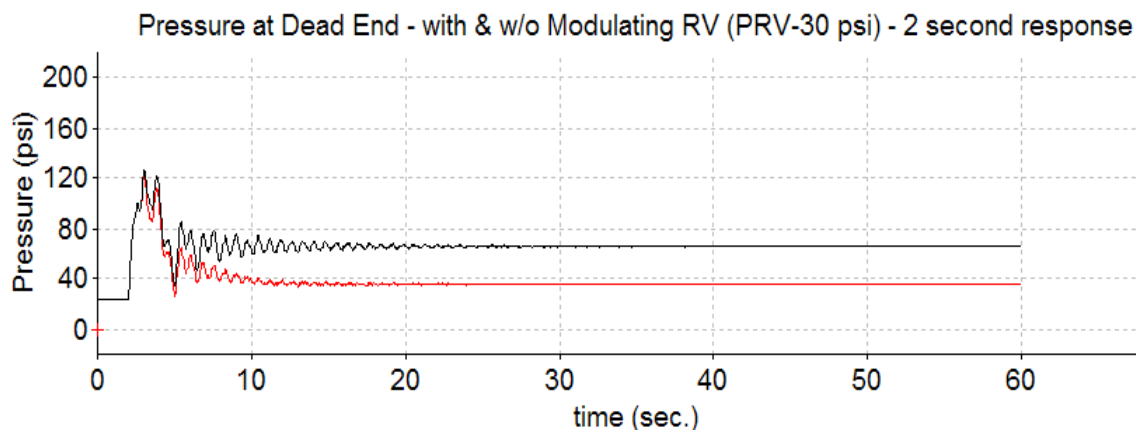


Figure T1–24 Pressure at Dead End – RV Automatic Modulation (2 sec.)

Training Exercise #2 – Pump Stations and Pumping Costs (pump design.p2k)


System Description - (Pump Design.P2K) It is necessary to pump 10000 gpm (water) from an elevation of 1000 feet to an elevation of 1900 feet using the arrangement shown in Figure T2-1. This arrangement is based on a requirement for a process used by a major industry. To accomplish this two pump stations are used as shown. Each station has multiple pumps in parallel. In order to control the flow one pump is equipped with a variable frequency drive (VFD) to vary the pump speed. The variation for this single pump is limited to 10% of rated speed. Your task is to determine the number of pumps required for each pump station and the speed required for the VFD pump. Assume that

each of the short pipe lengths are 50 feet and all pipe is 16 inch ductile iron (di). Note that Pipe2018 can model this arrangement using just 2 pump elements in parallel. One element will be for the identical multiple pumps and the second models the VFD pump. Also note that very precise control of the flows is required to maintain the level in the intermediate tank.

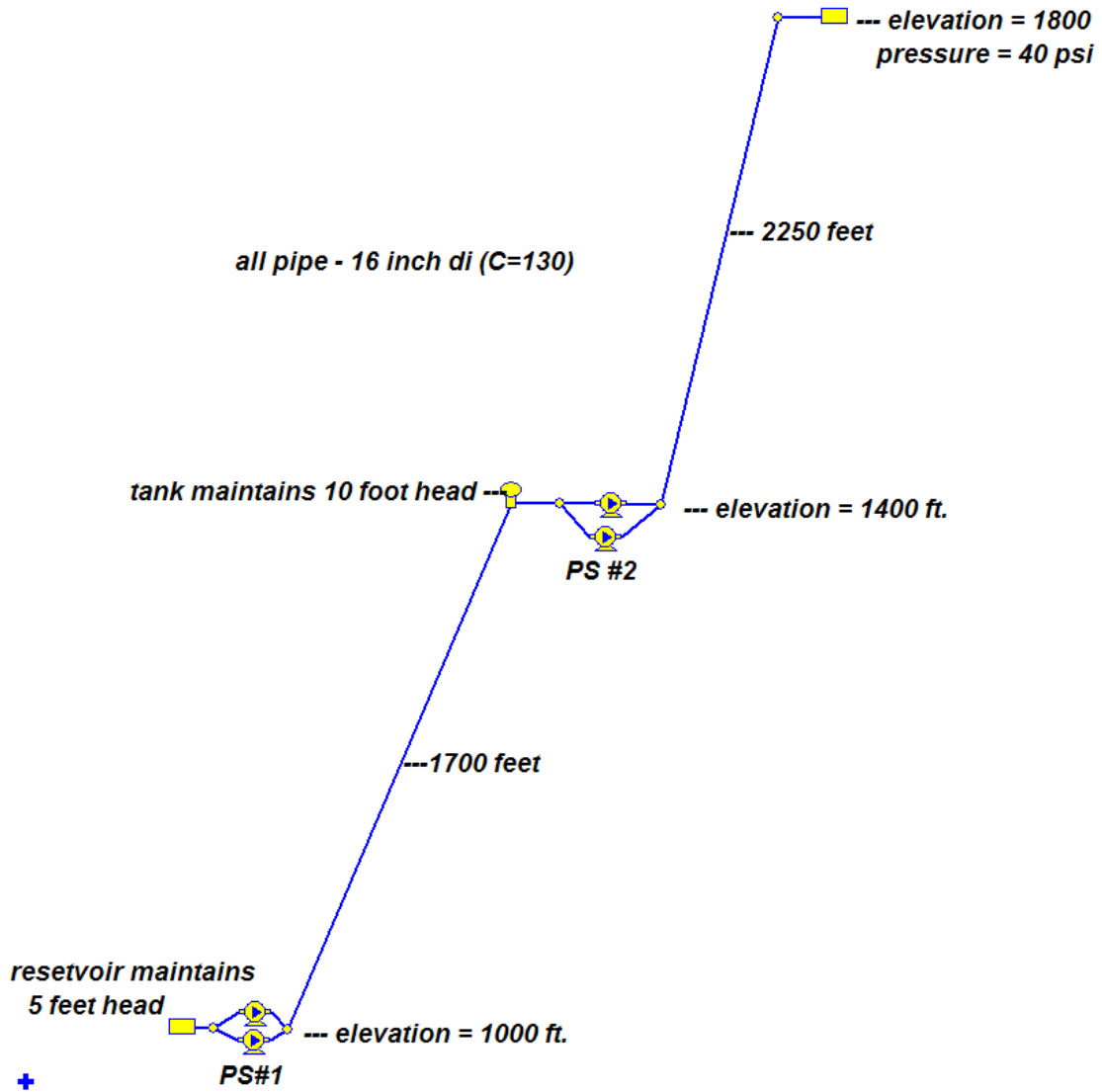
Additional analysis (pump design 2.p2k) -

- 1) Determine the cost/day for this pumping requirement. There are additional solutions for the pump arrangements. Determine an alternate solution and compare the pumping costs for both solutions. Power cost is \$0.08 (8 cents) per KWH
- 2) Determine if 12000 gpm can be pumped using the available pumps and the same arrangement. If so determine the number of parallel pumps required and the speed for the VFD pump. If you determine that a pump station is not capable of providing this flow make a recommendation that will upgrade the capability and provide the calculations to support your recommendation.
- 3) Develop System Curves for the two pump stations and plot these with multiple pump curves for the available pumps. This should provide additional insight into the performance of the pump stations.

Setting up the Model –The arrangement for the pump stations is shown in Figure T2-2. It is useful to develop a system curve and plot it with the multiple pump curves for parallel pumps as shown in Figure T2-3. This shows that four fixed speed parallel pumps are not adequate and either 3 identical pumps with the 4th operating at a speed ratio >1.0 or 4 parallel pumps with a 5th operating at a speed < 1.0 will be required. Hydraulically, either of these arrangements will be acceptable as long as the speed required for the VFD pump is within the specified range (.9 – 1.1). The better arrangement will be the one which uses less total power resulting in a lower operating cost.

To evaluate the pumping cost, set up a 24-hour EPS at 1 hour increments and enter the Power Cost ( or System Data/EPS). The report will give the Total Power Cost.

Solutions – One solution (*Pump Design.P2K*) which meets the specifications is for 3 parallel pumps and the VFD pump operating at a speed ratio of 1.0265 at PS #1 and 6 parallel pumps with the VFD pump operating at 1.057. The power cost for this solution is \$6035/day.



HEAD (ft)	FLOWRATE (gpm)	EFFICIENCY (%)
545.00	0.00	67.00
505.00	2000.00	75.00
345.00	4000.00	65.00

Data for PS#1

HEAD (ft)	FLOWRATE (gpm)	EFFICIENCY (%)
600.00	0.00	65.00
580.00	2000.00	73.00
500.00	4000.00	60.00

Data for PS#2

Figure T2-1 Data for Training Exercise 2

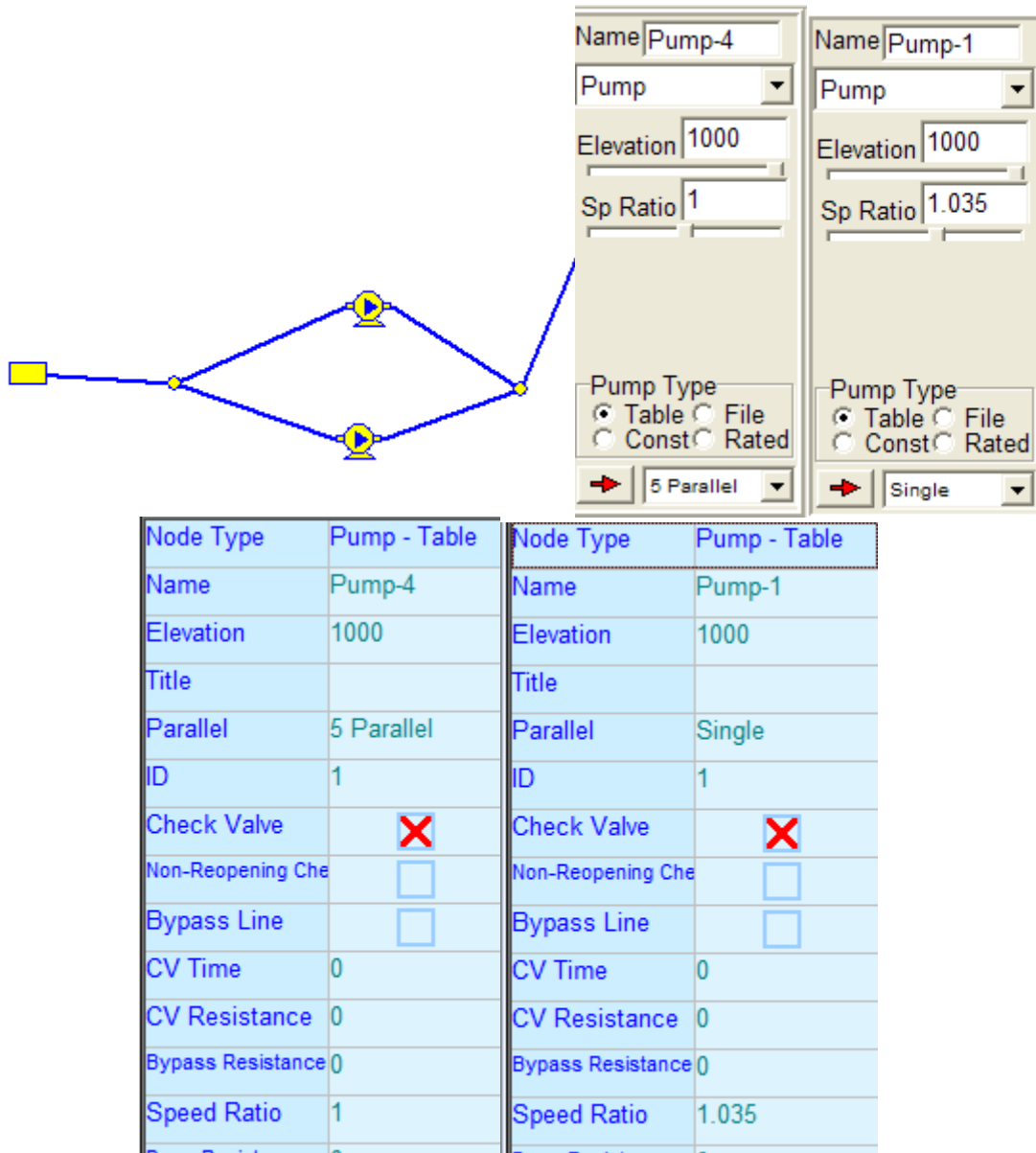


Figure T2-2 Pump Station Model for Training Exercise 2

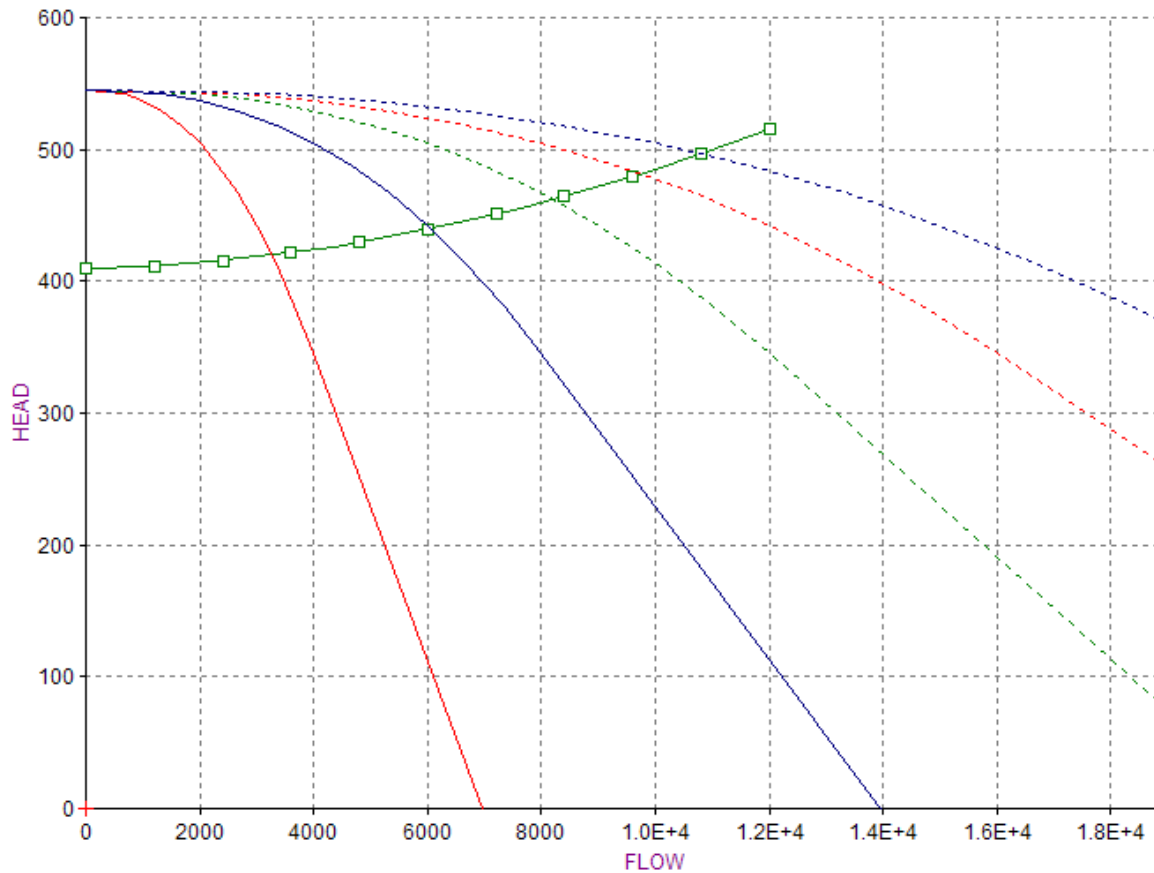


Figure T2-3 Pump Station #1 System Curve and Multiple Pump Curves

Training Exercise #3 – Hydraulic Analysis of Sprinkler System

System Description (*Demo Fire Sprinklers.P2K*) - A sprinkler system layout is shown in Figure T3-1 (plan view). Water is supplied by a connection to a city water main. A fire flow test at a nearby hydrant gives the data shown to characterize the supply to the sprinkler system. The sprinklers are ½ inch orifices and are fed through a 1 foot long 1 inch nipple (vertical with the ½ inch orifice exit 1 foot below connection). A 20 foot grid is provided to determine lengths. The connecting pipe (from the supply) rises 30 feet vertically to the sprinkler system (this length must be added to the total length). Set up an analysis with all 4 sprinklers operating. Assume all pipe has ID = 2.0 inches with a HW coefficient = 120.

Additional analysis - The minimum flow required through any sprinkler is 35 gpm. If this requirement is not met carry out additional analyses with a larger connection to the supply.

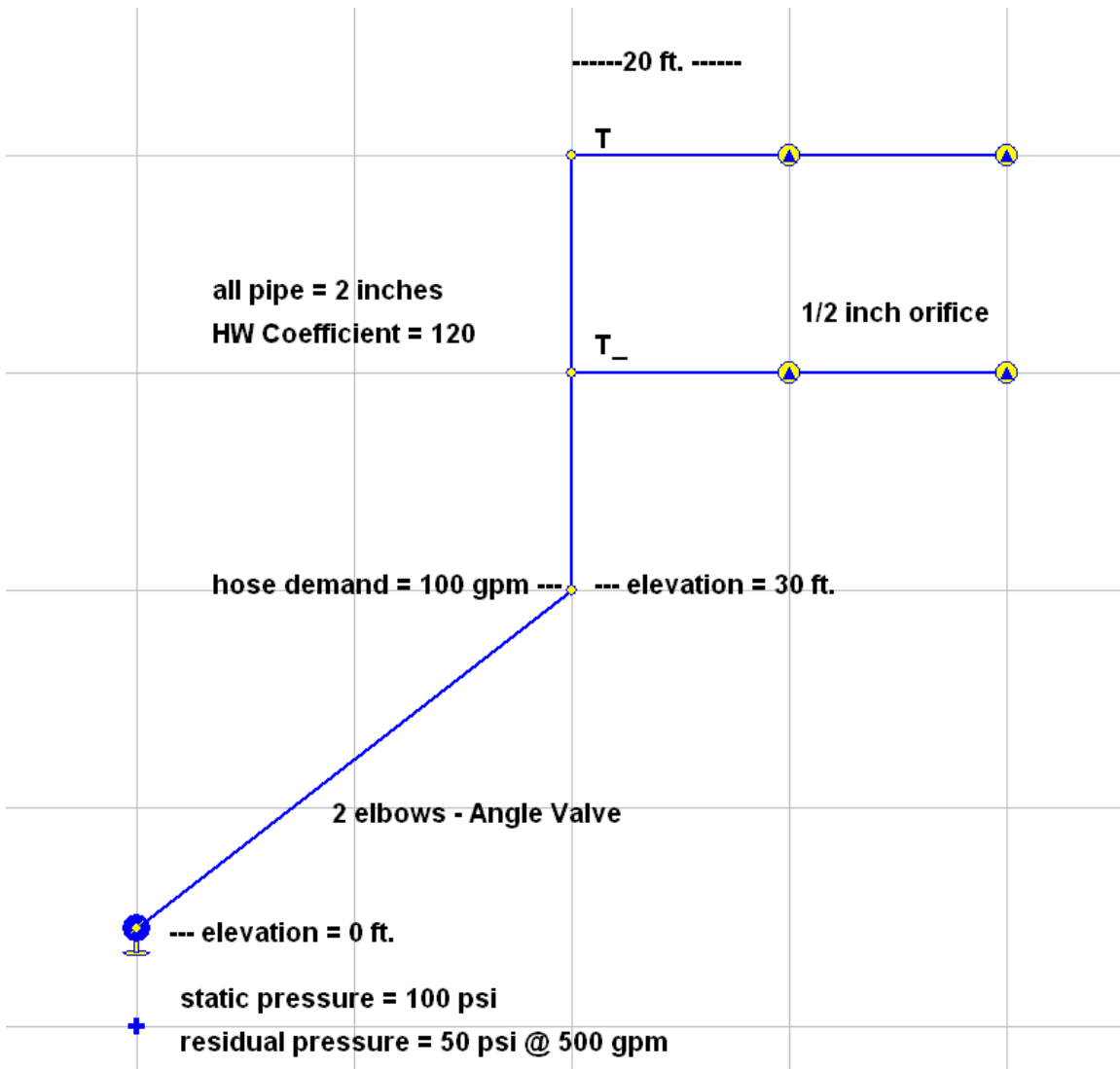


Figure T3-1 Data for Training Exercise 3



Sprinkler Constant Tool

Name	S-6	Node Type	Sprinkler/Leak
Sprinkler/Leak		Name	S-6
Elevation	30	Elevation	30
Constant	5.6	Title	
Length	1	On/Off	
Diameter	1	Constant	5.6
Elev Chg	-1	Length	1
Elbows	0	Diameter	1
		Elevation Change	-1
		Elbows	0

Sprinkler Data

Name	PS-1	Node Type	Rated Pressure Sup
Pressure Supply		Name	PS-1
Elevation	0	Elevation	0
Gage Dif	0	Title	
Static Pr	100	On/Off	
Res Pr	50	Ignore Changes	<input type="checkbox"/>
Res Flow	500	Gage Difference	0
<input checked="" type="checkbox"/> Rated		Static Pressure	100
Main Supply		Residual Pressure	50
		Residual Flow	500
		Main Supply	

Pressure Supply Data

Figure T3-2 Sprinkler and Pressure Supply Data for Training Exercise 3

Setting up the Model – Pipe2018 includes a tool for determining the sprinkler constant based on the orifice size. The use of this tool is illustrated in Figure T3-2 along with the setup screens for the sprinkler and pressure supply. Note that the data for the 1 foot long nipple is included with the sprinkler and the elevation change is entered with a (–) sign because the sprinkler nozzle is 1 foot below the piping system.

The hydraulic analysis of a sprinkler system often includes the requirement to provide for a fire hose demand at the supply or at some interior node (or both). For this exercise a hose requirement of 100 gpm is specified at the node where the riser pipe connects into the sprinkler system. This requirement is accommodated by specifying a demand of 100 gpm at that node. Note that the pipe from the supply to this node includes an additional

30 foot riser and there are several fittings in this line which should be modeled. Two additional T connections which should be included in the hydraulic analysis are noted.

Analysis Results - Figure T3-3 shows the pipe and sprinkler flows for the hydraulic analysis using the baseline data. This shows that the 35 gpm requirement is not being met. Two additional simulations are set up using a 3-inch and a 4-inch connection. This is done by providing Change Data for this pipe as shown in Figure T3-4. The Change Type is selected as Diameter and 2 additional simulations are set up. Figure T3-5 shows the pipe and sprinkler flows for a 3-inch diameter connection and this provides the required 35 gpm flow.

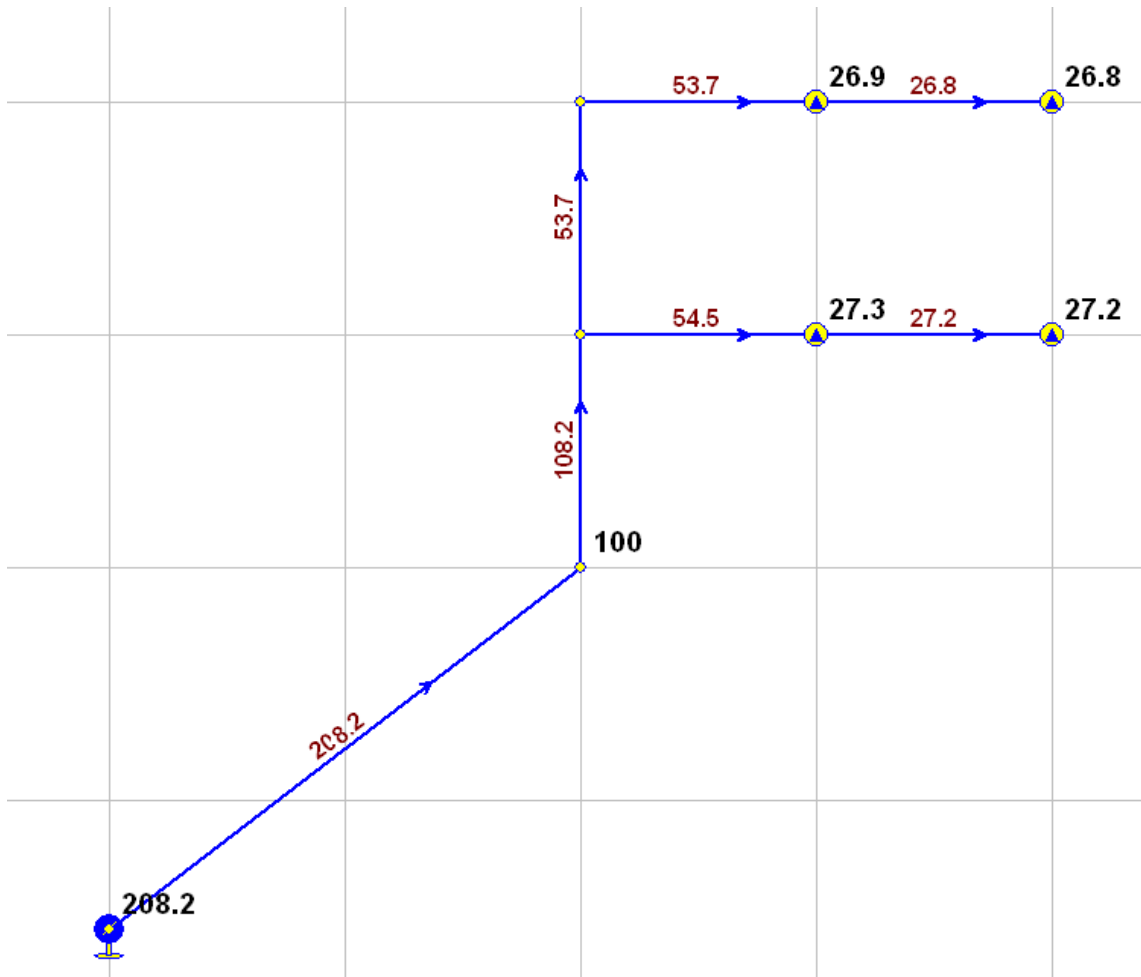


Figure T3-3 Pipe and Sprinkler Flows (2 inch connection) for Training Exercise 3

Pipe Changes	
Length	
Diameter	
Roughness	
Minor Loss	
Pipe Open	
Pipe Closed	
Delete This Change	

Time/Case	Value
1	D 3
2	D 4

Changes for 1		
Case	Change	Value
1	Diameter	3
2	Diameter	4

Figure T3-4 Changes to Increase Connecting Pipe Size for Training Exercise 3

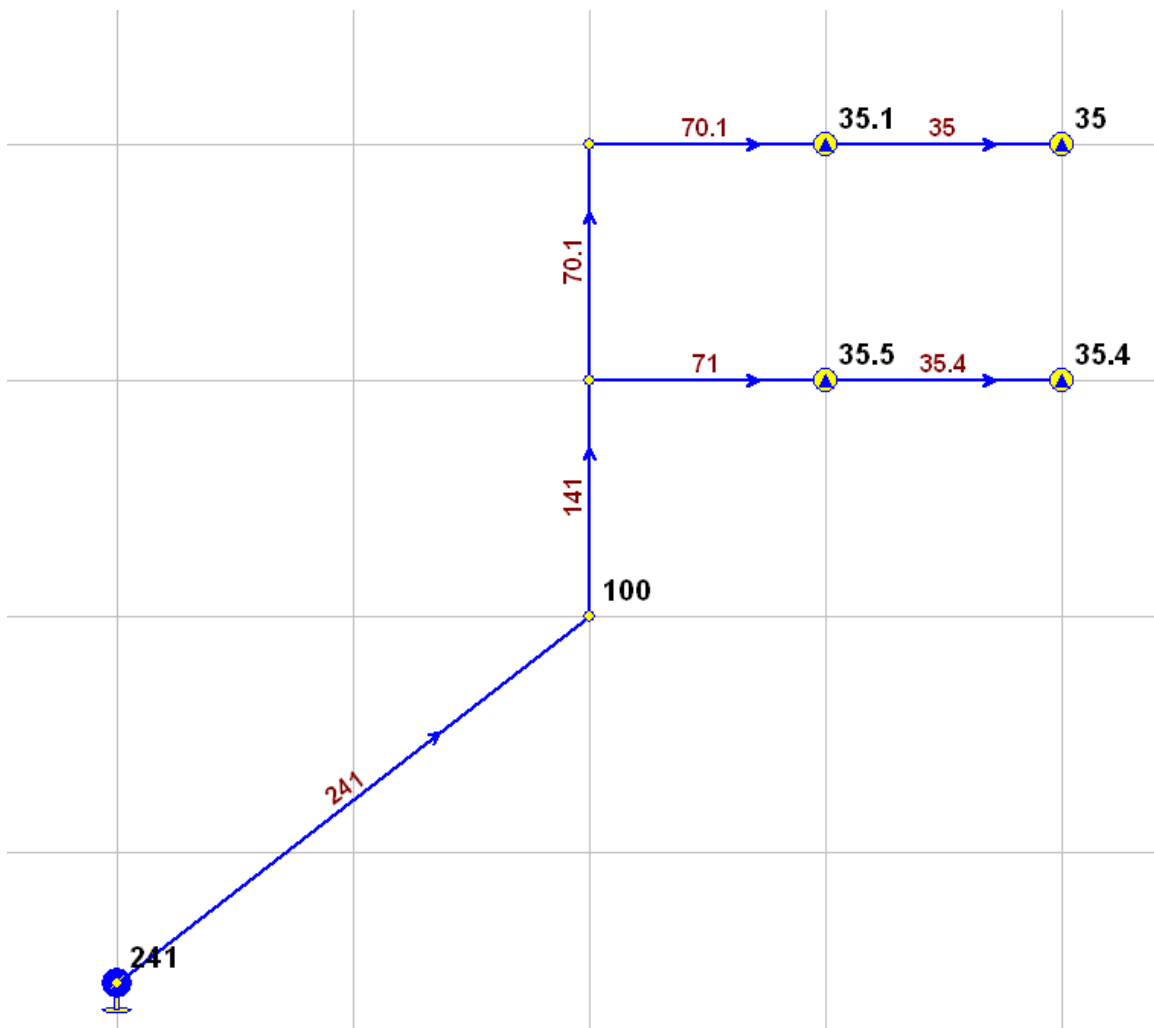


Figure T3-5 Pipe and Sprinkler Flows (3 inch connection) for Training Exercise 3

Section 4 - Case Studies

Case Study #1 - Landfill Gas Extraction Piping System (Landfill Gas Extraction.P2K)

Description – Pipe2018 : Gas provides an excellent modeling tool for designing and analyzing a landfill gas extraction system. There are several approaches to modeling the extraction system and a simple yet accurate modeling approach is illustrated below in Figure CS1-1. A compressor (fan – blower) at the collection point provides a vacuum on the piping system. The vacuum is usually on the order of a negative 15 – 30 inches of water (around 1 psi or less). This vacuum must be sufficient to provide a vacuum at each collection point sufficient to pull in the required amount of gas. For this example it is assumed that each of the collection nodes will collect 60 SCFM (standard cubic feet/minute) of gas. Thirteen collection nodes are modeled at the end of 4-inch pvc pipes (light). The rest of the collection system is 8-inch pvc (dark).

A control valve will be positioned at the well head collection nodes. The piping system and compressor must be sized so a sufficient vacuum is pulled at each of the collection points. The required analysis is easily done by designating the desired inflow at each well head and calculating the vacuum pressure required. If this pressure is sufficient to allow the control valve to be set to a proper setting to set the flow using the available pressure drop then the collection system will work. If this is not the case either larger pipes or a larger compressor will be required. Conversely if the pressure differences are significantly larger than required then smaller pipes or a smaller compressor may be used.

Model Data – The Gas System Data screen is shown in Figure CS1-2. For this example methane properties are used. However, landfill gas will not be pure methane so the gas properties for the extracted gas should be used. The Gas model provides a Lookup Properties tool which will give the necessary properties for methane at 86 degrees F. as shown in Figure CS1-2 (specific gravity, viscosity etc). Note the flow units of SCF/min and pressure units of inches of water are used. These units are commonly used for landfill gas extraction studies.

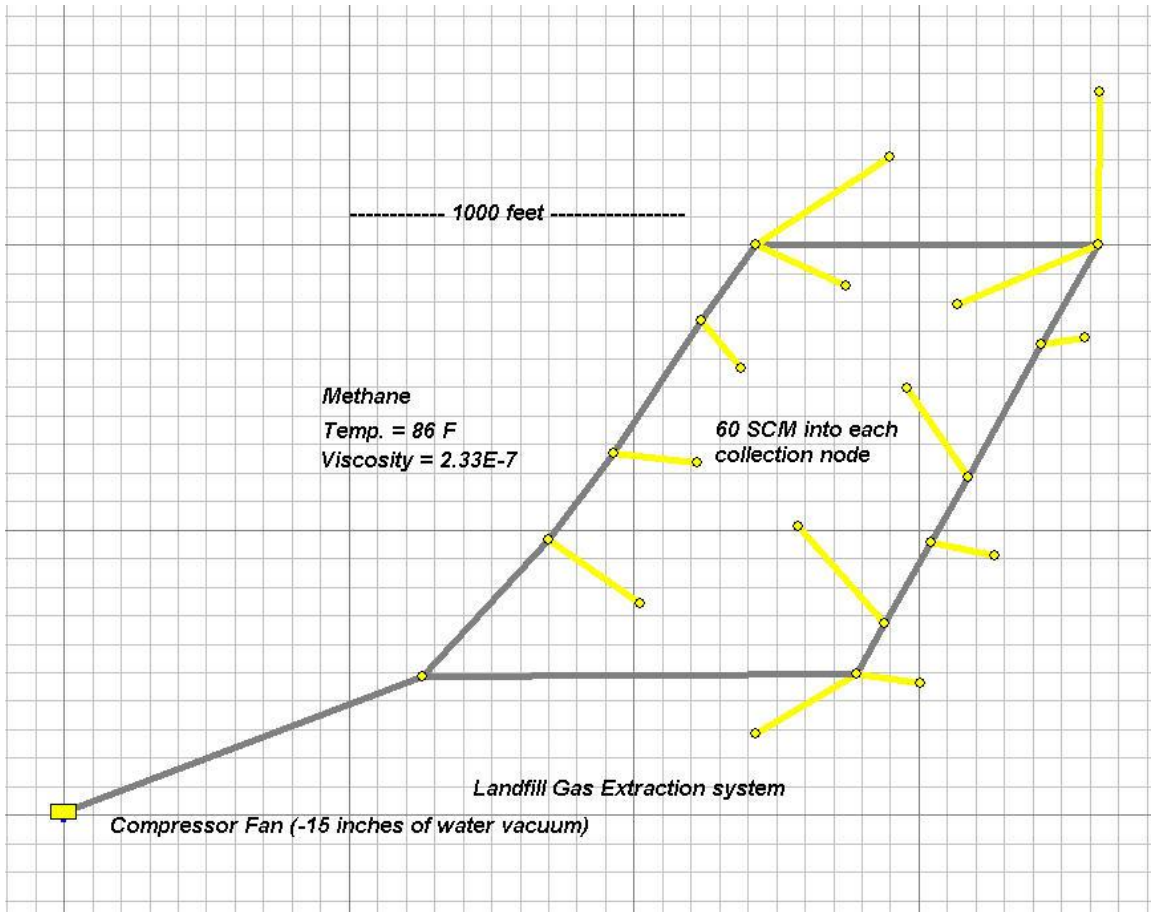


Figure CS1-1 Landfill Gas Extraction System

KYnetic System Data icon: 100
3.74
035

Map | Map Settings | System Data | Other Data | Setup/Defaults | Report

Simulation Specs | Other | EPS | Reports | Preferences | Skeletonize/Subset

Gas System Data

SI Units Flow Units SCF/min

Pressure Units inches water (g)

Operating Temp 86

Specific Gravity 5545

Ratio of Specific Heats 1.31

Absolute Viscosity 2.33E-07

Gas Density Use

Molecular Wt 16.04 Use

Critical Temp. Use

Critical Pres. Use

System Type Gas

Lookup Properties

Demand Pattern Clear Pattern

Pattern Name none

Select Pattern

Change Pattern Clear Pattern

Pattern Name

Select Pattern

Name	P-6	
Pipe Type		
Diam	4	
Mtrl	pvc	
Rtng	65	
Length	560	<input type="checkbox"/> F
Rough	0.1	<input checked="" type="checkbox"/> F

Name	P-6
Pipe Type	ISCO 4" - 65 - 4
Length	535
Roughness	0.1
Fittings	

Pipe Data

Name	R-1
Reservoir	
Elevation	80
Pressure	-15

Node Type	Reservoir (Pressur
Name	R-1
Elevation	80
Title	
Pressure	-15

Compressor Data

Name	J-20
Junction	
Elevation	100
Demand	-60
Dm Type	1

Node Type	Junction Single Dem
Name	J-5
Elevation	100
Demand	-60
Demand Type	1

Junction Data

Figure CS1-4 Pipe, Reservoir and Junction Data

The pipes are all pvc and a roughness of 0.1 millifeet was used as illustrated in Figure CS1-4. Node elevations are noted in Figure CS1-3. Because the analysis is for gas the elevations will have a very small effect on the results. However, elevation data may be entered for each node. The reservoir represents the suction pressure for the compressor and should be set to the desired value. For this example we used -15 inches of water. This implies that a compressor is required which produces 15 inches of water pressure at a flow of 780 SCFM. The junction data includes a negative demand of 60 SCFM to simulate the amount of gas extracted from each well head.

Results – The pressures and flows for the Pipe2018 : Gas simulation are shown in Figure CS1-5. The analysis shows that the pressure drop across the control valve at the well heads vary from 6.7 to 4.9 inches of water (assuming the well head pressure is atmospheric). This should be sufficient to overcome losses through the control valves and control the flows. Required valve settings can also be determined. For example, the valve setting for the smallest pressure differential (4.9 inches) means that the control valve will be set such that 60 SCFM will cause a pressure drop of 4.9 inches of water. This data allows the selection of an appropriate valve. It should be noted that identical results will be obtained if the reservoir representing the compressor suction is replaced by a compressor (pump) which operates at 15 inches and 780 SCFM while discharging the gas at atmospheric pressure.

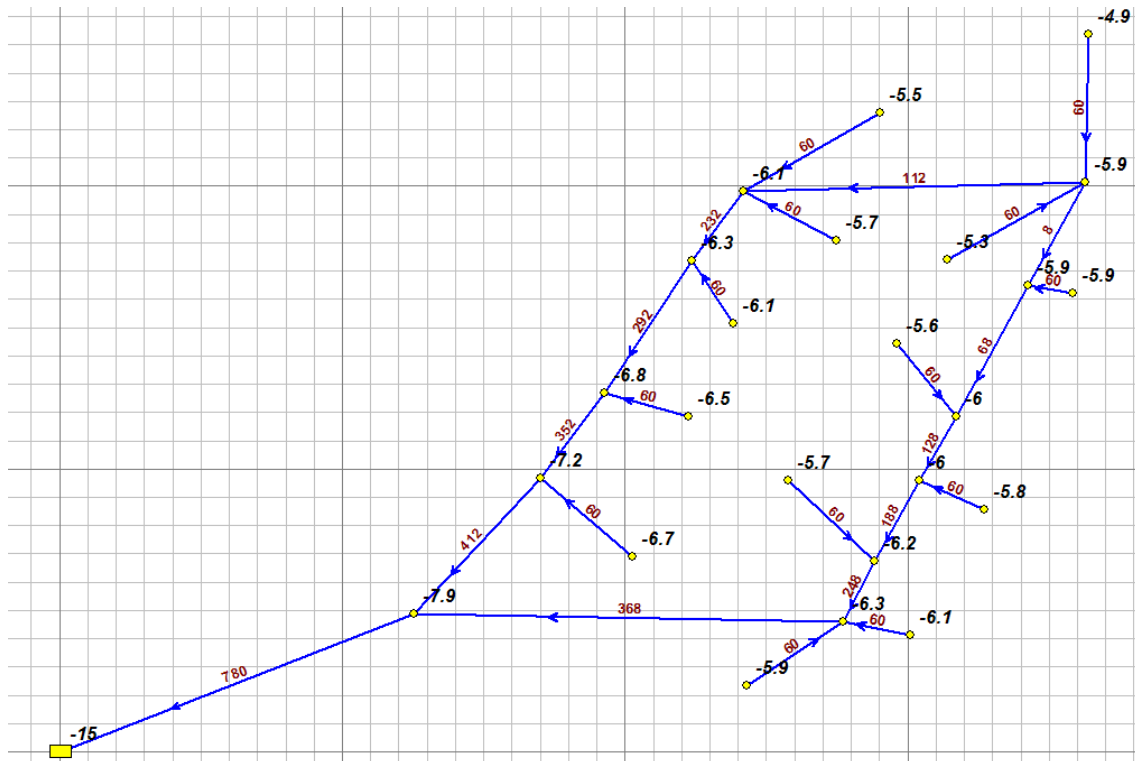


Figure CS1-5 Pressures (inches of water) and Flows (SCFM) in Collection System

A further illustration of the power of modeling for design is shown in Figure CS1-6. For this analysis the pipes highlighted were closed (essentially removed from the collection system). The resulting pressures and flows are shown. The results show that removing the upper pipe lowers the vacuum pressures 30% or so. Removing the lower pipe results in an unacceptable design (vacuum is not attained at some collection nodes).

Case Study #2 Modeling Air/vacuum Valves with Surge (Air Vacuum Valves.P2K)

Figure CS2-1 shows a simple Surge model which simulates a pump trip and evaluates the effect of 2 air/vacuum valves. The pump station delivers 350 gpm @ 100 feet of head and is modeled using a Pump Junction Node. A pump trip is modeled by ramping the flow from 350 gpm down to 0 in 4 seconds. Figure CS2-2 shows the pressures at 2 locations when there is no surge protection (air/vacuum valves are closed).

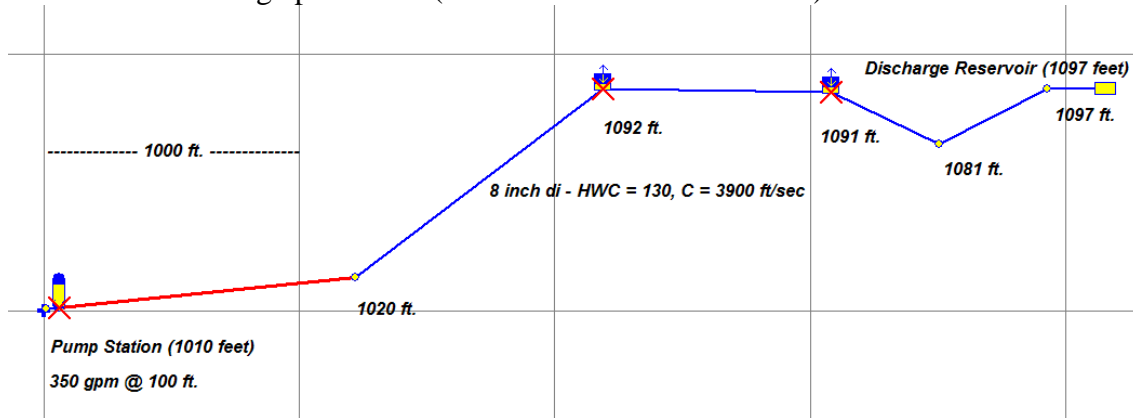


Figure CS2-1 Surge Model with Air/vacuum Valves

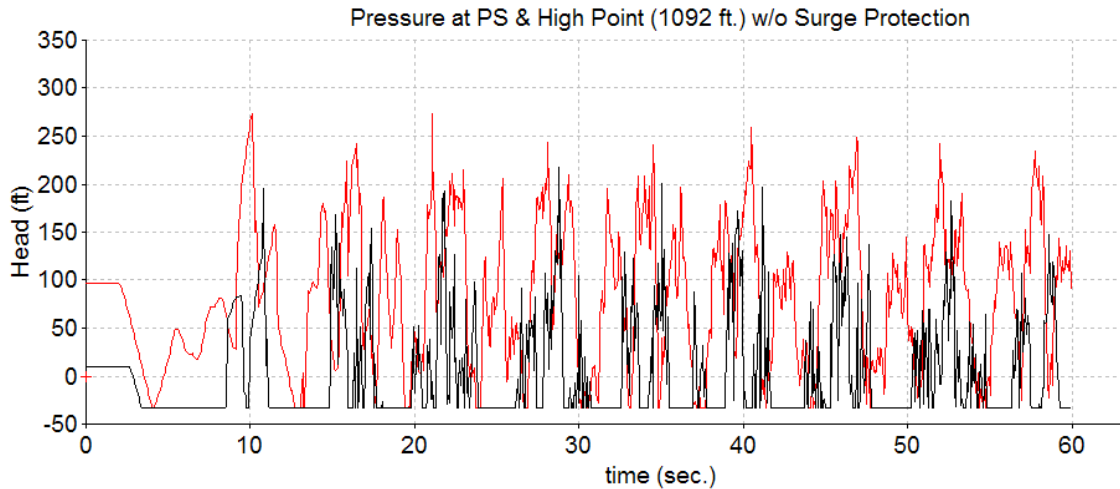


Figure CS2-2 Surge Model Results - no Air/vacuum Valves


Figure CS2-3 shows data for three different setups for the 2 air/vacuum valves. For the first the outflow orifice is much smaller than the inflow orifice. This design is intended to allow a lower controlled release of air and prevent “air slam”. The results for the PS and high point are shown in Figure CS2-4 and very small pressure spikes occur when the air is all expelled.

It is possible that an air valve could experience a short delay before air enters the pipeline. For rapid pressure drops (pump trip) this could allow pressures significant lower than atmospheric pressure to develop prior to activation. Surge allows the user to specify

a delay as shown in Figure CS-2b. The results obtained with a delay for one air valve (but not the other) are shown in Figure CS-5.


A third set of results were obtained using the same 2 inch orifice for inflow and outflow. The results for this analysis are shown in Figure CS-6. As shown significant pressure spikes occur as the result of “air slam”.

Device Data	
Inflow D	2
Outflow D	0.25
Init Vol	0
Delay	0


Node Type	1/2 Stage Air Vacu
Name	J-4
Elevation	1092
Title	
On/Off	
Initial Gas Volume	0
Inflow Diameter	2
Outflow Diameter	0.25
Delay	0
Disc Coef	0

2-Stage

Device Data	
Inflow D	2
Outflow D	0.25
Init Vol	0
Delay	1

Node Type	1/2 Stage Air Vacu
Name	J-4
Elevation	1092
Title	
On/Off	
Initial Gas Volume	0
Inflow Diameter	2
Outflow Diameter	0.25
Delay	1
Disc Coef	0

With a Delay

Device Data		Node Type	1/2 Stage Air Vacu
Inflow D	2	Name	J-4
Outflow D	2	Elevation	1092
Init Vol	0	Title	
Delay	0	On/Off	
		Initial Gas Volume	0
		Inflow Diameter	2
		Outflow Diameter	2
		Delay	0
		Disc Coef	0

Single Stage

Figure CS2-3 Surge AV Data Screens

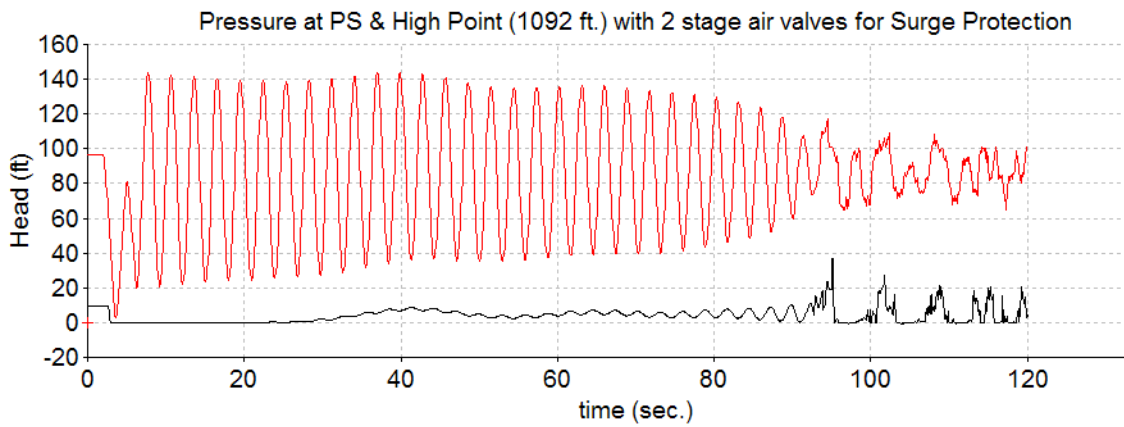


Figure CS2-4 Surge Model Results – 2 Stage Air/vacuum Valves

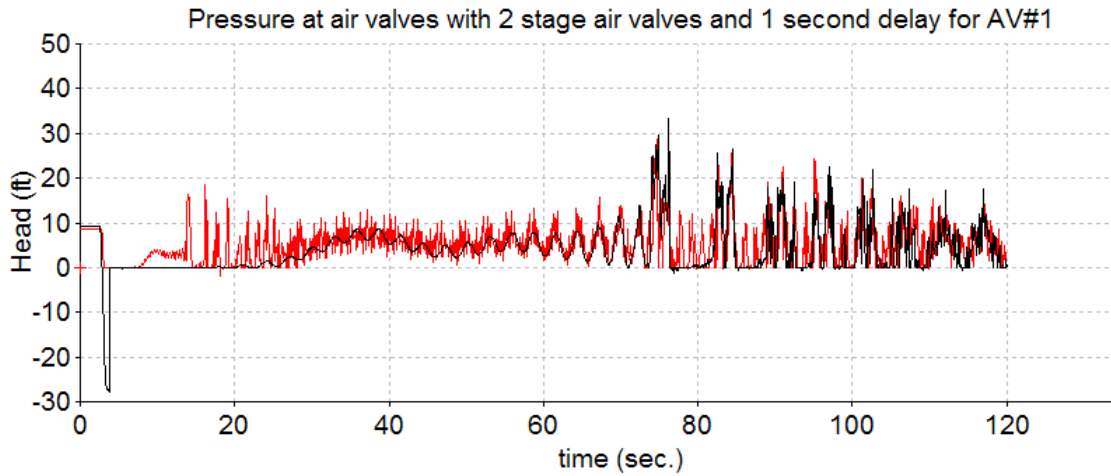


Figure CS2-5 Surge Model Results –2 Stage Air/vacuum Valves - 1 sec. delay

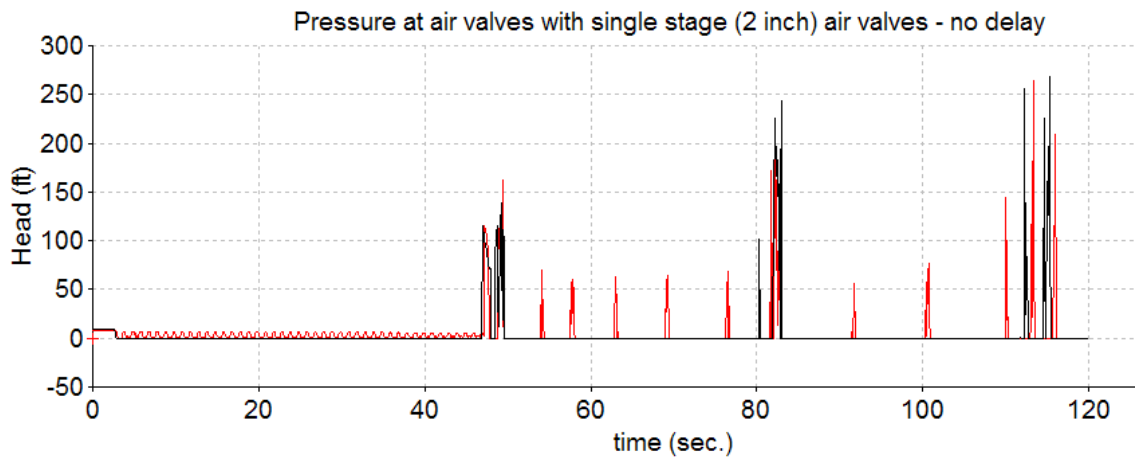


Figure CS2-6 Surge Model Results – Single Stage Air/vacuum Valves

Campus Pipe Distribution Facilities Modeling

Pipe2018 has unique capabilities to model facilities piping systems. This provides a powerful modeling platform for all the various distribution systems which may be part of a campus or industrial facility physical plant. The following distribution system types can be modeled and analyzed using Pipe2018.

- 1) potable water distribution system including fire hydrants
- 2) chilled water supply and return systems
- 3) hot water distribution systems
- 4) gas distribution systems (natural gas, air or any gas)
- 5) saturated or superheated steam distribution systems

All of the Pipe2018 series models employ the same easy-to-use graphical user interface (GUI) which means that once a user becomes familiar with the GUI they can utilize the full range of the Pipe2018 capabilities and models. The user merely selects the

appropriate module from the Pipe2018  or System Data | Simulation Specs menu.

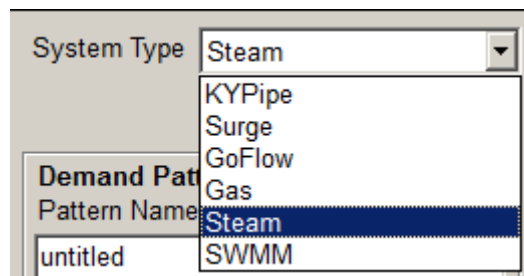


Figure CF-1 Pipe2018 Module Selection

KYPipe and GoFlow use the powerful KYPipe engine (as well as Surge for steady state) which analyzes all kinds of liquid distribution systems. The Steam model is used for saturated and superheated steam distribution and the Gas model handles all gas distribution systems. In addition a transient liquid flow model (Surge) is available to do pressure surge analysis on any liquid flow system. This adds an extremely important capability to this comprehensive package of distribution system modeling software.

The following simple modeling examples are presented in this section to illustrate modeling of Campus distribution systems. The data file names are noted.

- 1) **Potable Water Distribution & Fire Flows** (*Campus Potable Water.P2K*)
- 2) **Chilled Water – supply & return** (*Campus Chilled Water.P2K*)
- 3) **Hot Water Distribution** (*HotWater.P2K*)
- 4) **Gas Distribution** (*Campus Gas Distribution.P2K*)
- 5) **Saturated Steam Distribution** (*Campus Steam Distribution.P2K*)
- 6) **Superheated Steam Distribution** (*Campus Superheated Steam.P2K*)

A scaled map of a small but typical campus is shown in Figure 2. This is used as a background map for the following Campus Facilities distribution system examples.



Figure CF-2 Scaled Campus Map

1) Potable Water Distribution Model (Campus Potable Water.P2K)

Figure CF-3 shows the layout of a potable water system. This system is fed from a water main in the city distribution system which has the characteristics shown based on a fire hydrant test of a nearby fire hydrant. Figure CF- 4 provides additional data on pipe sizes, roughness and demands. The data file for this example is Campus Potable Water.P2K (Examples button – 6 Campus Facilities folder). For the sake of simplicity all elevations are set at 400 feet. Demands of 75 gpm are located at each building as shown in Figure CF-4 (large nodes) The supply is accurately modeled in Pipe2018 using a Variable Pressure Supply as shown in Figure CF-4. This device accounts for the pressure drop at the supply based on the amount of flow going to the campus. Data boxes for nodes and pipes are also shown in Figure CF-4

Five fire hydrants are located as shown. The following simulations were carried out:

- 1) Average Demands for Each Building (75 gpm)
- 2) Peak Demands for Each Building (GDF=1.4)
- 3) Fire Flow at Average Demands and Peak Demands



Figure CF-3 Potable Water System With Scaled Campus Map

Campus Facilities Example 1- Results

1) Average Demands for Each Building (75 gpm)

Figure CF-5 shows pressures at the buildings for this analysis.

2) Peak Demands for Each Building (GDF=1.4)

The demands at each building were increased to 105 gpm (75×1.4). Figure CF-6 shows pressures at the buildings for this analysis.

3) Fire Flow at Average and Peak Demands

The fire flow which can be delivered at each hydrant while maintaining 20 psi at all locations in the piping system is determined by selecting the Fireflow Calculations option shown below. The Fireflow report is also shown. Figures CF-7 & CF-8 show the available fireflows for these cases.

Fireflow with specified min pressure Minimum Pressure for Fireflows 20

Static Pressure Limit 20 (nodes with static pressure below this value will be ignored)

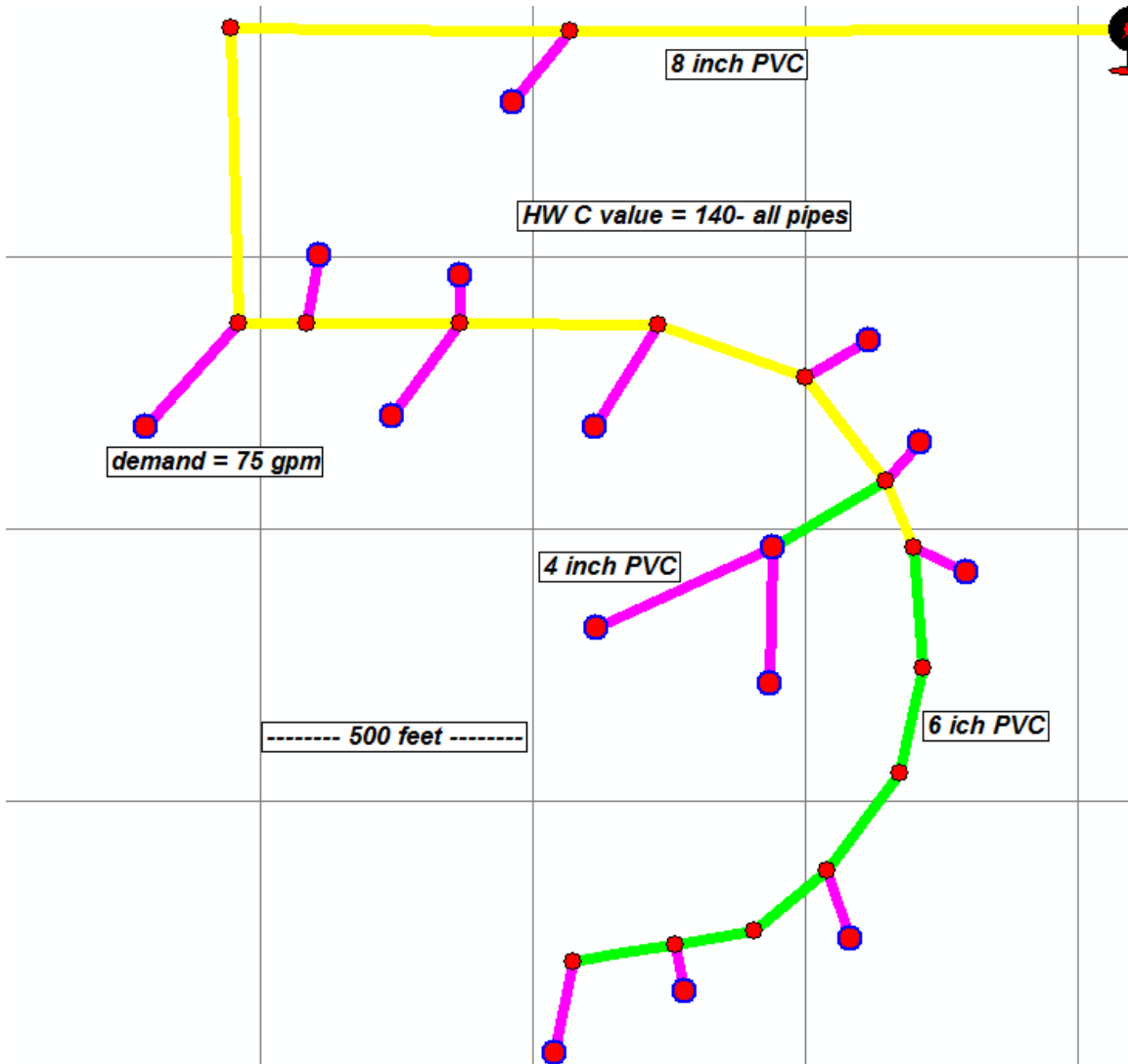
Fireflow Nodes

- Selected Hydrants
- All Hydrants
- Selected Junctions Nodes
- All Junction Nodes

Generate Flushing Report (Hydrants and Blowoffs)

Clear Old Results

Hydrant Node	Elevation	Demand gpm	Static Pressure	Flow-1 gpm	Flow-2 gpm	Node-2
H-4	400.0	0.0	65.6	831.3	745.9	J-25
H-5	400.0	0.0	75.0	1448.1	1134.8	J-25
H-1	400.0	0.0	60.3	456.0		
H-3	400.0	0.0	62.2	660.5	631.1	J-25
H-2	400.0	0.0	61.1	553.2	540.7	J-25



Name	VP-1
Pressure Supply	
Elevation	400
Gage Dif	0
Static Pr	90
Res Pr	75
Res Flow	2000
<input checked="" type="checkbox"/> Rated	

Node Type	Rated Pressure Supply
Name	VP-1
Elevation	400
Title	
On/Off	<input checked="" type="checkbox"/>
Ignore Changes	<input type="checkbox"/>
Gage Difference	0
Static Pressure	90
Residual Pressure	75
Residual Flow	2000

Rated Pressure Supply Data

Name	J-29
Junction	
Elevation	400
Demand	75
Dm Type	1

Node Type	Junction Single Demand
Name	J-1
Elevation	400
Demand	75
Demand Type	1

Junction Data

Name	P-29
Pipe Type	
Diam	4
Mtrl	PVC
Rtng	
Length	360 <input type="checkbox"/> F
Rough	140 <input checked="" type="checkbox"/> F
Fittings	<input type="checkbox"/> Closed

Fittings	
	28
90Elbow	<input checked="" type="checkbox"/>
Tee std.	<input type="checkbox"/>
Tee elbow	<input checked="" type="checkbox"/>
GtV oper	<input type="checkbox"/>
GlbV ope	<input type="checkbox"/>
AngleV o	<input type="checkbox"/>
Meter, di	<input type="checkbox"/>
Ent.strai	<input type="checkbox"/>
Exit	<input type="checkbox"/>
Other K	0
Sum K's	2.25

Name	P-29
Pipe Type	PVC - 4
Length	360
Roughness	140
Fittings	28

Pipe and Fittings Data

Figure CF-4 Data for Potable Water System Model

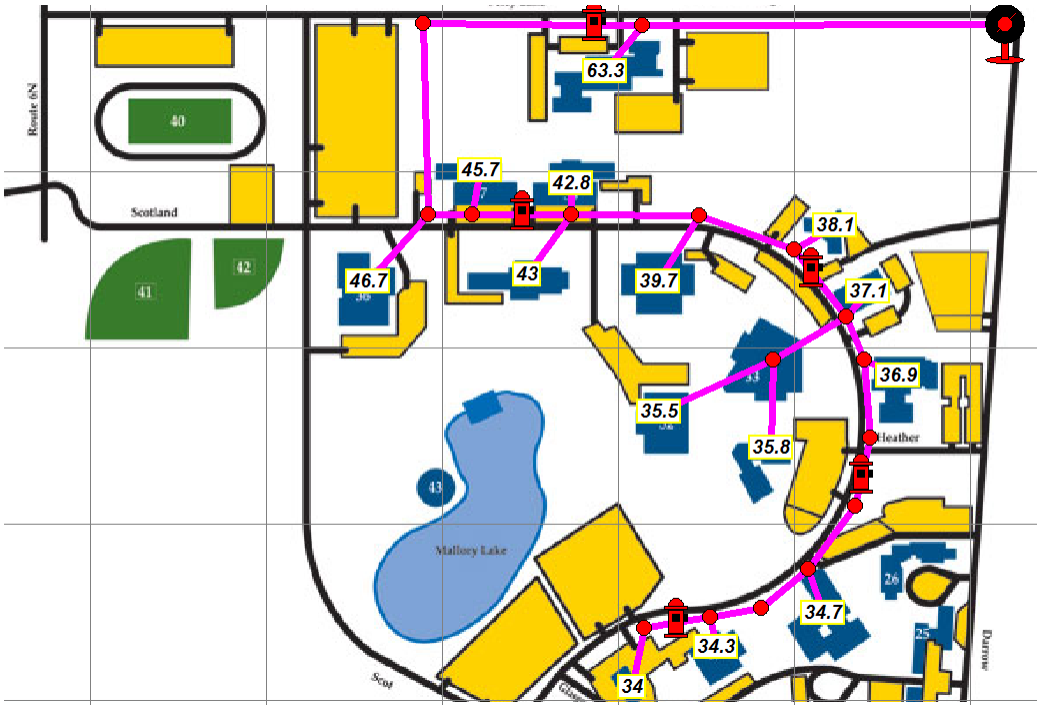


Figure CF-5 Pressures @ Average Flow (1125 gpm)

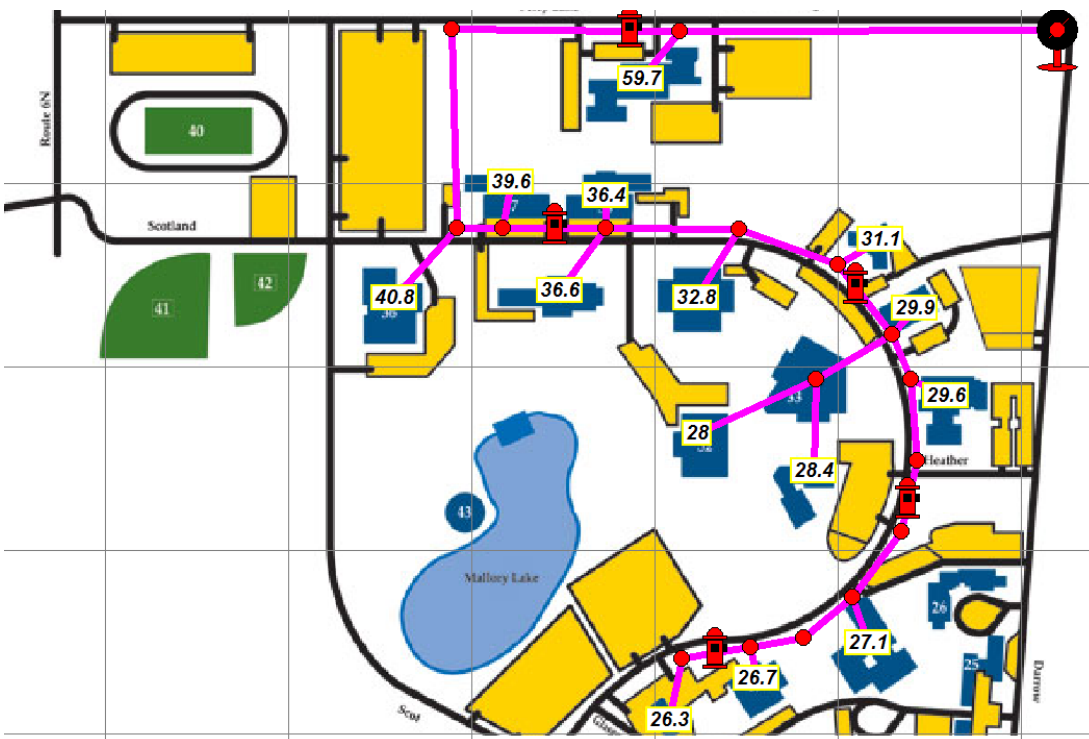


Figure CF-6 Pressures @ Peak Flow (GDF-1.4)



Figure CF-7 Fire Flow @ 20 psi Minimum (average)

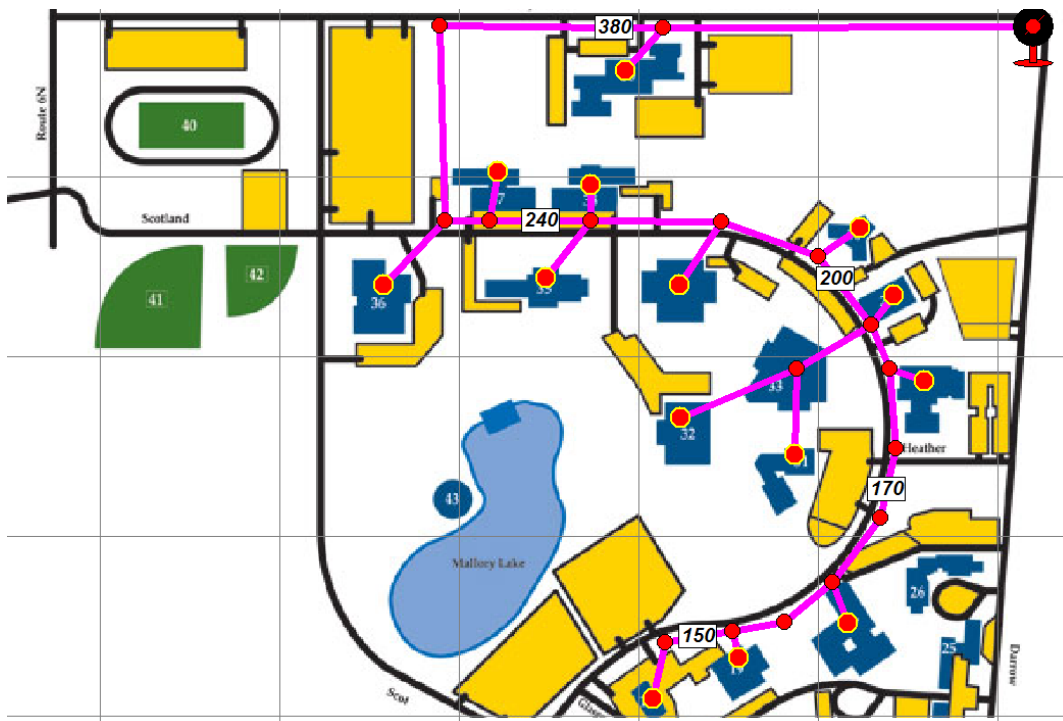


Figure CF-8 Fire Flow @ 20 psi Minimum (peak)

2) Chilled Water Model (Campus Chilled Water.P2K)

A Pipe2018 Model for a Chilled Water Supply and Return system is shown in Figure CF-9. The system consists of the higher pressure supply piping and lower pressure return piping as shown. All main pipes are 6-inch and pipes to and from buildings are 4-inch. Flows to buildings are controlled using flow control valves as shown. Additional modeling details are shown below. Loads of 100 and 80 gpm for each building were analyzed. The data file for this example is Campus Chilled Water.P2K (Examples button – 6 Campus Facilities folder). Typical results are shown in Figure CF-10

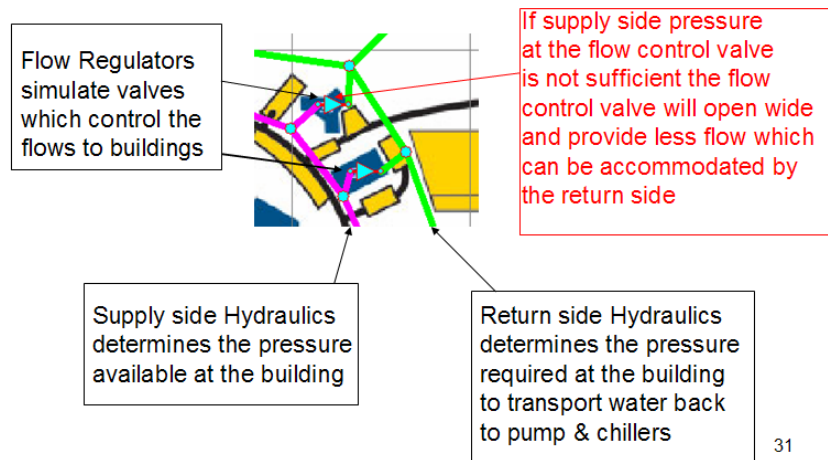
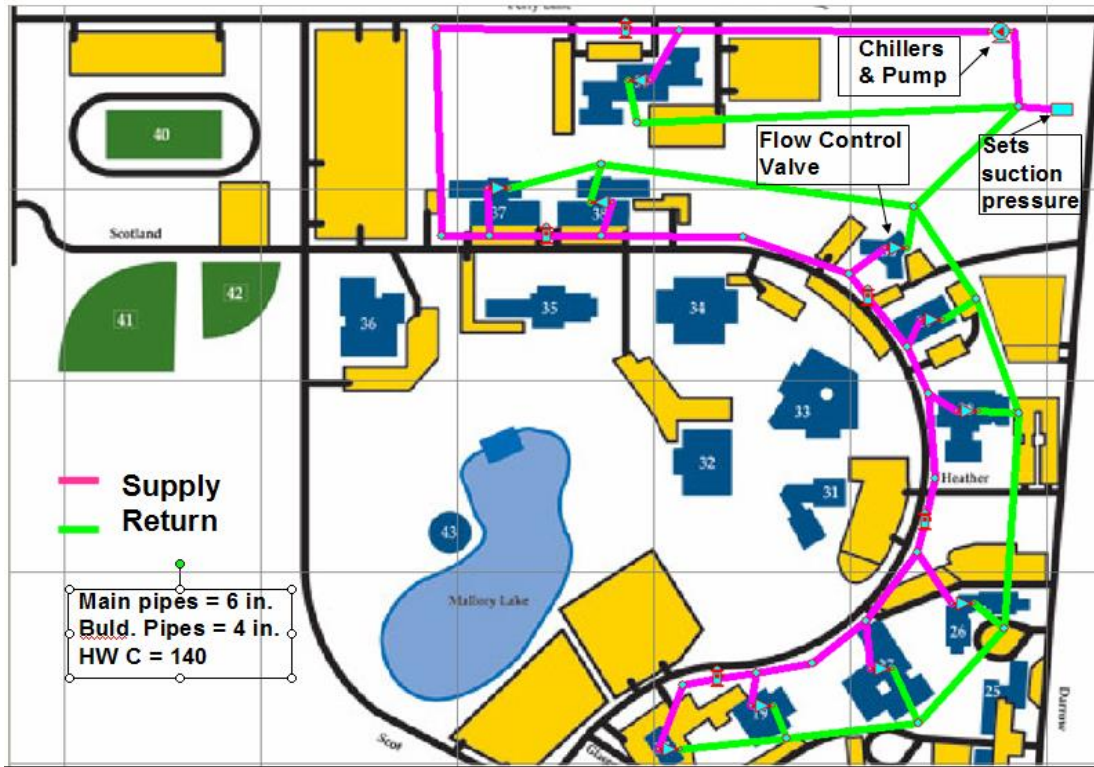


Figure CF-9 Chilled Water Model

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Results – Peak and Average Loads

REGULATING VALVE REPORT

VALVE LABEL	VALVE TYPE	VALVE SETTING (psi or gpm)	VALVE STATUS	UPSTREAM PRESSURE (psi)	DOWNSTREAM PRESSURE (psi)	THROUGH FLOW (gpm)
RV-1	FCV-1	100.00	ACTIVATED	33.31	9.47	100.00
RV-10	FCV-1	100.00	ACTIVATED	15.96	14.71	100.00
RV-2	FCV-1	100.00	ACTIVATED	59.39	0.39	100.00
RV-3	FCV-1	100.00	ACTIVATED	28.89	8.99	100.00
RV-4	FCV-1	100.00	ACTIVATED	20.69	7.91	100.00
RV-5	FCV-1	100.00	ACTIVATED	18.65	10.57	100.00
RV-6	FCV-1	100.00	ACTIVATED	17.79	12.56	100.00
RV-7	FCV-1	100.00	ACTIVATED	15.65	15.53	100.00
RV-8	FCV-1	100.00	WIDE OPEN	15.56	15.56	89.31
RV-9	FCV-1	100.00	WIDE OPEN	15.59	15.59	54.67

Peak Load

Unable to maintain load

RV-1	FCV-1	80.00	ACTIVATED	48.68	6.90	80.00
RV-10	FCV-1	80.00	ACTIVATED	35.11	11.50	80.00
RV-2	FCV-1	80.00	ACTIVATED	68.12	0.26	80.00
RV-3	FCV-1	80.00	ACTIVATED	45.32	6.58	80.00
RV-4	FCV-1	80.00	ACTIVATED	39.01	5.87	80.00
RV-5	FCV-1	80.00	ACTIVATED	37.37	7.97	80.00
RV-6	FCV-1	80.00	ACTIVATED	36.67	9.61	80.00
RV-7	FCV-1	80.00	ACTIVATED	34.77	12.25	80.00
RV-8	FCV-1	80.00	ACTIVATED	34.54	12.46	80.00
RV-9	FCV-1	80.00	ACTIVATED	34.34	12.81	80.00

Average Load

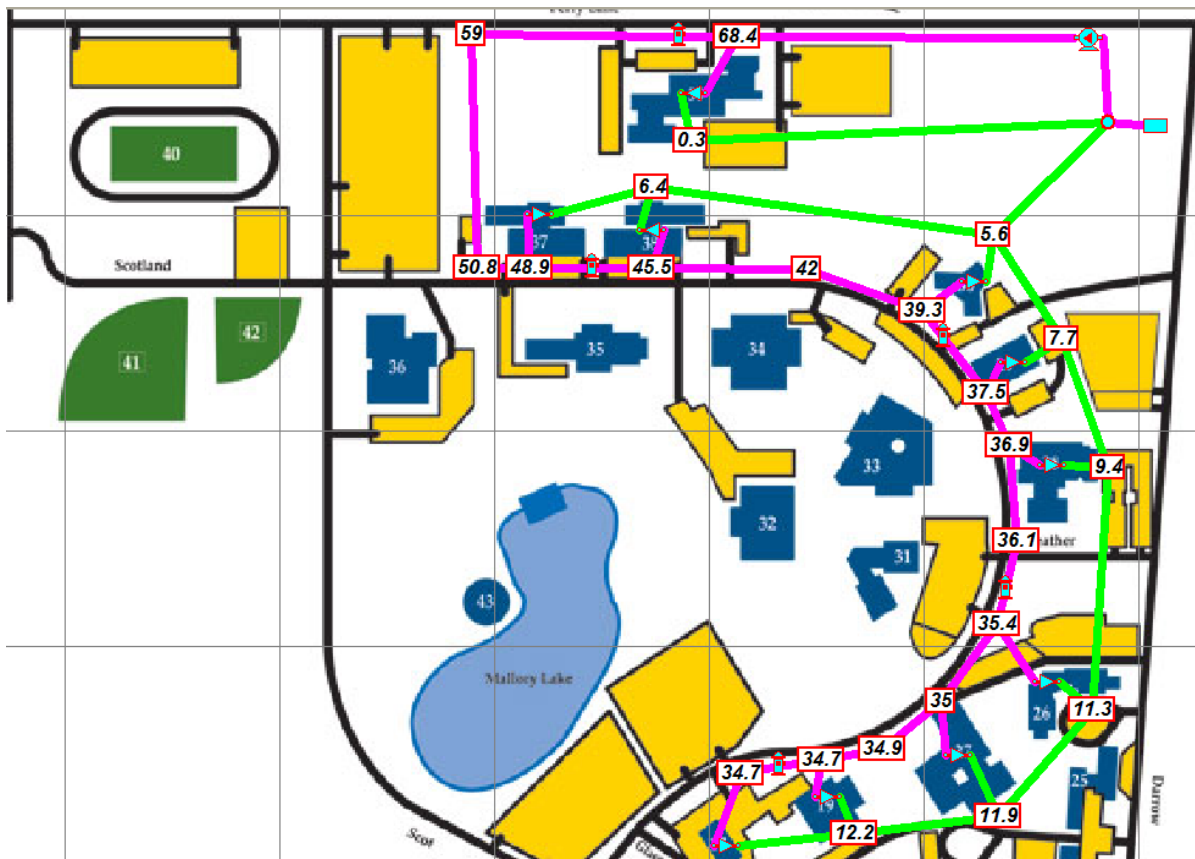


Figure CF-10 Chilled Water Model Results

3) Hot Water Model (HotWater.P2K)

A Pipe2018 Model for a Hot Water Distribution System is shown in Figure CF-11. The main feature of this distribution system is that the water is superheated. Significant temperature changes occur as the flow is distributed from the boiler to the buildings. This causes significant changes in the density and the viscosity of the water. It is necessary to provide a temperature vs. density & viscosity table for the superheated water. This is done using a Pipe2018 Tool as shown in Figure CF-12. It is also necessary to employ the Darcy Weisbach head loss formula because of the variation in the properties of the hot water. Input data for the supply (boiler) and all nodes are provided as input data. These values are shown in Figure CF-13. The data file for this example is HotWater.P2K (Examples button – 6 Campus Facilities folder).

The model was analyzed for a range of building loads (8 – 14.8 gpm). Pressures at the buildings are shown in Figure CF-14 for the low and high loads. Figure CF-15 shows the pressure variations at several buildings. Figure CF-16 shows the tabulated results which include the density and viscosity variations.

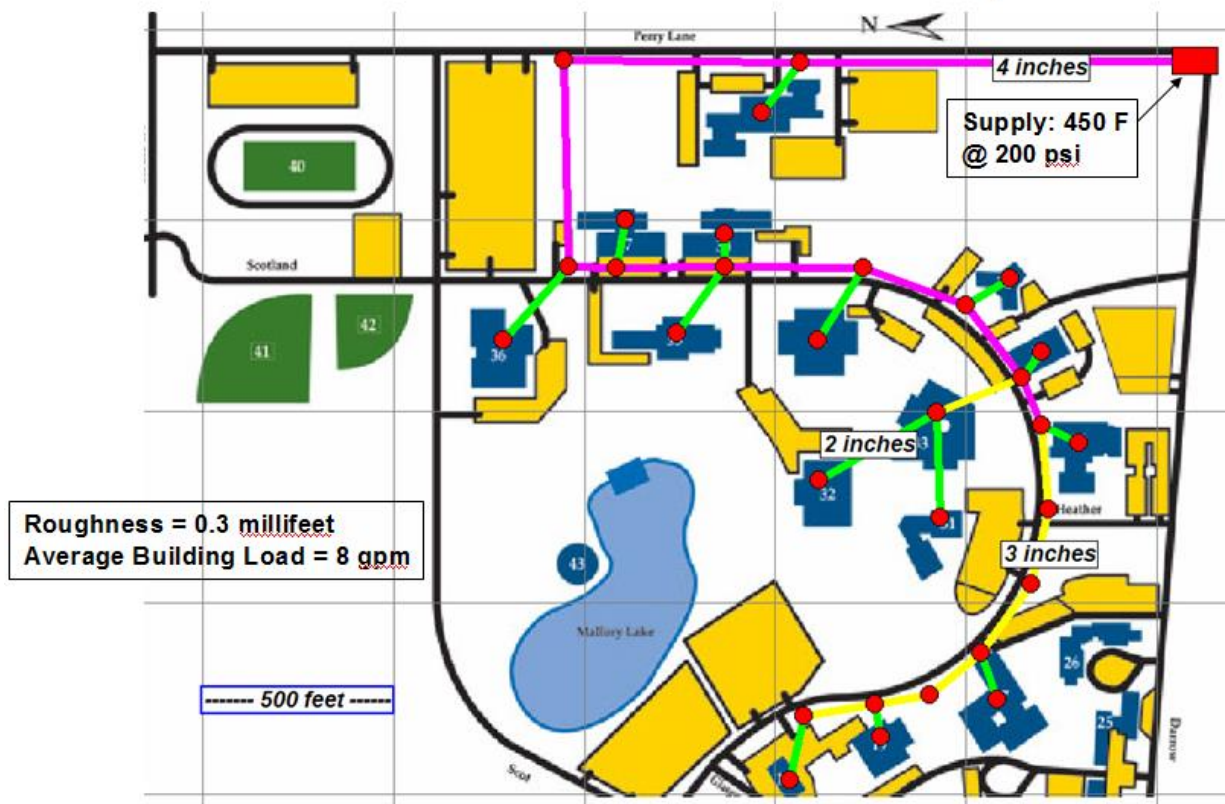


Figure CF-11 Hot Water Distribution System Model

Temperature Vs. Densit_Viscosity			
	Temperature	Density	Viscosity
Unit	F	l/m ³	ft ² /sec
1	40	62.4	0.0000166
2	60	62.4	0.0000122
3	80	62.2	0.000018
4	100	62	0.0000142
5	150	60	0.0000048
6	200	55	0.00000341
7	300	50	0.000002
8	400	40	0.000001
9			
10			

Hot Water File

Name: R-1

Reservoir

Elevation: 400

Grade: 861.4

Node Type	Reservoir (Grade)
Name	R-1
Elevation	400
Title	
On/Off	<input checked="" type="checkbox"/>
Ignore Changes	<input type="checkbox"/>
Grade	861.4

Reservoir Data

User Data

Temperature

450

Temperature	450
-------------	-----

Reservoir Temperature User Data

Figure CF-12 Hot Water Properties File and Supply Data



Figure CF-13 Hot Water Temperatures @ Buildings

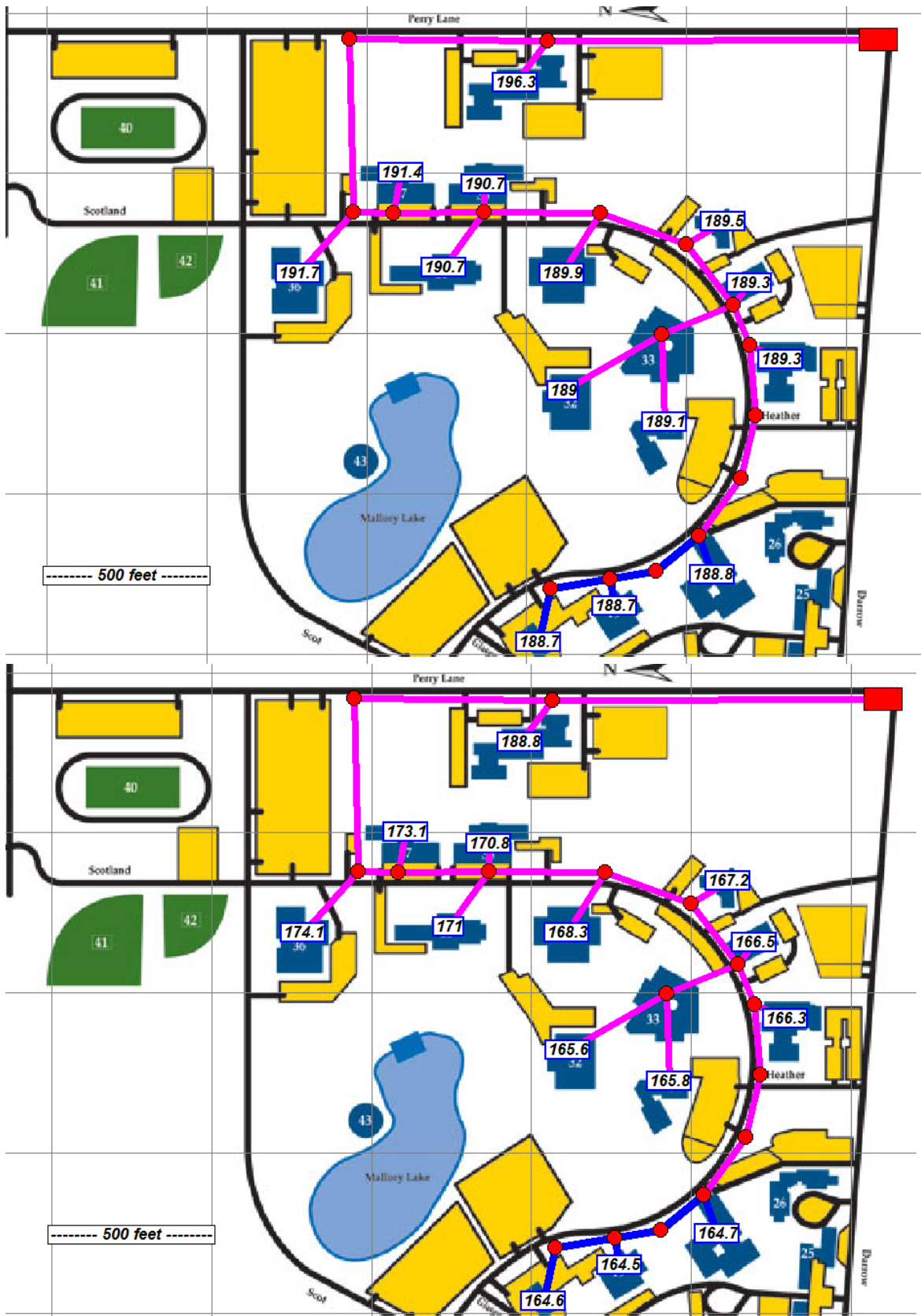


Figure CF-14 Pressures – Load = 8 gpm (upper) & 14.8 gpm (lower)

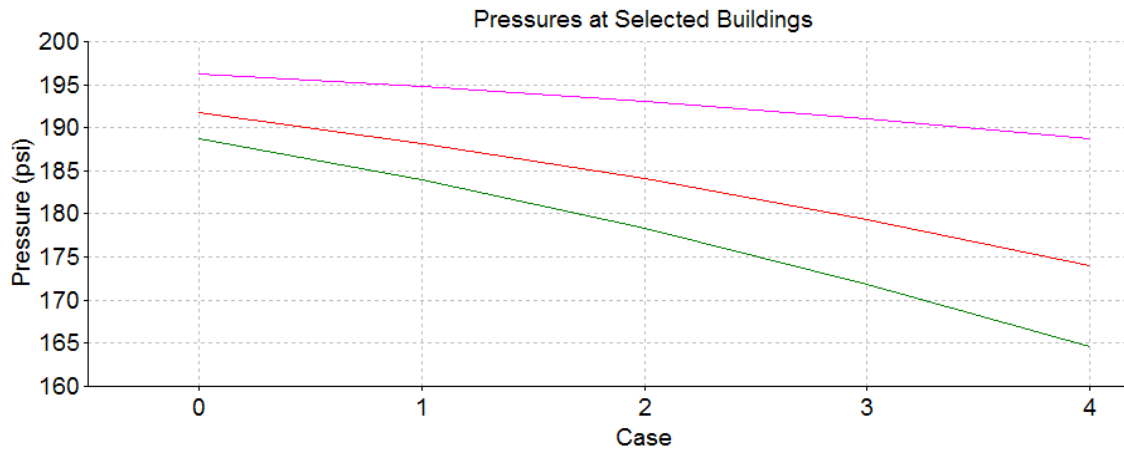


Figure CF-15 Pressures at Selected Buildings

PIPE NAME	NODE #1	NODE #2	FLOWRATE (gpm)	HEAD LOSS (ft)	MINOR LOSS (ft)	LINE VELO. (ft/s)	HL/1000 (ft/ft)	Kine. Viscos. (ft ² /s)	Ave Density	Pressure Drop (psi)	Mass Flow (lb/s)	Ave. Temp
P-1	R-1	J-2	193.21	24.98	0.00	4.93	24.25	0.0000122	52.450	9.098	22.577	412.5
P-10	J-10	J-11	44.20	1.22	0.00	2.01	5.55	0.0000031	53.750	0.456	5.293	225.0
P-11	J-11	J-12	28.80	0.42	0.00	1.31	2.45	0.0000034	55.000	0.159	3.529	200.0
P-12	J-12	J-23	28.80	0.37	0.00	1.31	2.45	0.0000034	55.000	0.140	3.529	200.0
P-13	J-2	J-14	14.40	0.82	0.00	1.47	4.82	0.0000012	42.500	0.242	1.363	375.0
P-14	J-15	J-17	182.80	5.55	0.00	4.67	19.83	0.0000015	45.000	1.735	18.326	350.0
P-15	J-15	J-16	14.40	0.63	0.00	1.47	4.86	0.0000015	45.000	0.197	1.444	350.0
P-16	J-17	J-5	154.00	5.08	0.00	3.93	14.12	0.0000015	45.000	1.589	15.439	350.0
P-17	J-17	J-18	14.40	0.44	0.00	1.47	4.86	0.0000015	45.000	0.137	1.444	350.0
P-18	J-6	J-19	14.40	0.69	0.00	1.47	4.93	0.0000020	50.000	0.240	1.604	300.0
P-19	J-7	J-20	14.40	0.44	0.00	1.47	4.93	0.0000020	50.000	0.154	1.604	300.0
P-2	J-2	J-3	224.05	18.36	0.00	5.72	29.61	0.0000012	42.500	5.418	21.214	375.0
P-20	J-8	J-21	14.40	0.55	0.00	1.47	5.03	0.0000027	52.500	0.202	1.684	250.0
P-21	J-11	J-22	14.40	0.67	0.00	1.47	5.12	0.0000034	55.000	0.254	1.764	200.0
P-22	J-23	J-13	14.40	0.13	0.00	0.65	0.66	0.0000034	55.000	0.048	1.764	200.0
P-23	J-23	J-24	14.40	0.46	0.00	1.47	5.12	0.0000034	55.000	0.176	1.764	200.0
P-24	J-13	J-25	14.40	0.03	0.00	0.37	0.16	0.0000034	55.000	0.010	1.764	200.0
P-25	J-4	J-1	14.40	1.26	0.00	1.47	4.86	0.0000015	45.000	0.395	1.444	350.0
P-26	J-17	J-26	14.40	0.13	0.00	0.65	0.61	0.0000015	45.000	0.040	1.444	350.0
P-27	J-5	J-27	14.40	1.07	0.00	1.47	4.86	0.0000015	45.000	0.334	1.444	350.0
P-28	J-7	J-28	34.20	0.79	0.00	1.55	3.29	0.0000020	50.000	0.274	3.810	300.0
P-29	J-28	J-29	14.40	1.78	0.00	1.47	4.93	0.0000020	50.000	0.616	1.604	300.0
P-3	J-3	J-4	217.65	15.11	0.00	5.56	27.99	0.0000014	43.750	4.592	21.214	362.5
P-30	J-28	J-30	14.40	1.38	0.00	1.47	4.93	0.0000020	50.000	0.479	1.604	300.0
P-4	J-4	J-15	197.20	2.77	0.00	5.03	23.05	0.0000015	45.000	0.864	19.770	350.0
P-5	J-5	J-6	132.25	3.04	0.00	3.38	10.49	0.0000018	47.500	1.004	13.995	325.0
P-6	J-6	J-7	111.24	1.80	0.00	2.84	7.49	0.0000020	50.000	0.624	12.391	300.0
P-7	J-7	J-8	61.11	0.30	0.00	1.56	2.34	0.0000024	51.250	0.108	6.978	275.0
P-8	J-8	J-9	45.26	1.27	0.00	2.05	5.77	0.0000027	52.500	0.463	5.293	250.0
P-9	J-9	J-10	45.26	1.15	0.00	2.05	5.77	0.0000027	52.500	0.420	5.293	250.0

Figure CF-16 Hot Water Model – Tabulated Results

4) Natural Gas (methane) Distribution (Campus Gas Distribution.P2K)

Figure CF-17 shows the layout of a campus Natural Gas (methane) Distribution Model. This system is supplied from a gas main in the city gas distribution system at 120 psi. Pressure regulators are used to reduce the pressures to the levels desired. The arrangement of the pressure regulators is shown in Figure CF-18 along with additional modeling data. Figure CF-17 provides additional data on pipe sizes, roughness and demands. Properties for the gas are input with the System Data as shown in Figure CF-18. Pipe2018 provides a gas properties Look-Up Tool as shown. The data file for this example is Campus Gas Distribution.P2K (Examples button – 6 Campus Facilities folder). For the sake of simplicity all elevations are set at 400 feet. Demands of 300 MSCF/day are located at each building.

Results of the compressible flow analysis are shown in Figures CF-19 (building pressures) and CF-20 (tabulated results).



Figure CF-17 Gas Distribution Model

Gas System Data	
SI Units <input type="checkbox"/>	Flow Units <input type="text" value="MSCF/day"/>
	Pressure Units <input type="text" value="psi (abs)"/>
	Operating Temp <input type="text" value="75"/>
	Specific Gravity <input type="text" value=".5545"/>
	Ratio of Specific Heats <input type="text" value="1.31"/>
	Absolute Viscosity <input type="text" value=".000000233"/>
Gas Density <input type="text"/>	<input type="checkbox"/> Use
Molecular Wt <input type="text"/>	<input type="checkbox"/> Use
Critical Temp. <input type="text"/>	<input type="checkbox"/> Use
Critical Pres. <input type="text"/>	

Figure CF-18 Additional Gas Distribution Model Details



Figure CF-19 Gas Distribution Model Results – Building Pressures

===== RESULTS FOR THIS SIMULATION FOLLOW =====

PIPE NO.	NODE #1	NODE #2	FLOW (USFU)	LOSS (USPU)	VELOCITY (FT/S)	DENSITY (#/CF)	FRICTION FACTOR	AREA RATIO
P-1	J-18	J-2	300.000	2.09	83.22	.081	.0173	.096
P-10	J-10	J-11	900.000	.35	61.04	.083	.0157	.071
P-11	J-11	J-12	600.000	.13	41.00	.082	.0169	.047
P-12	J-12	J-23	600.000	.11	41.17	.082	.0169	.048
P-13	O-RV-2	J-10	900.000	.17	60.50	.084	.0157	.070
P-14	J-15	J-17	-600.000	.20	37.74	.089	.0169	.044
P-15	J-15	J-16	300.000	.74	76.68	.088	.0173	.089
P-16	J-17	J-5	-1500.000	1.33	92.35	.091	.0145	.107
P-17	J-17	J-18	600.000	2.04	156.41	.086	.0156	.180
P-18	J-6	J-19	300.000	.72	70.12	.096	.0173	.081
P-19	J-7	J-20	300.000	.47	66.90	.101	.0173	.077

JUNCTION NAME	NODE TITLE	DEMAND (USFU)	PRESSURE (USPU)	PRESSURE (PSIA)	PRESSURE (PSIG)	DENSITY (#/CF)
J-1		300.00	29.54	29.54	14.84	.083
J-10		.00	29.83	29.83	15.13	.084
J-11		.00	29.48	29.48	14.78	.083
J-12		.00	29.34	29.34	14.65	.082
J-13		.00	28.02	28.02	13.33	.078
J-15		.00	31.82	31.82	17.12	.089
J-16		300.00	31.08	31.08	16.38	.087
J-17		.00	32.01	32.01	17.32	.090
J-18		300.00	29.98	29.98	15.28	.084
J-19		300.00	34.05	34.05	19.35	.095

Figure CF-20 Gas Distribution Model – Tabulated Results

5) Saturated Steam Distribution System (Campus Steam Distribution.P2K)

Figure CF-21 shows the layout of a campus Saturated Steam Distribution Model. This system is supplied from a Steam Plant at 120 psi. Figure CF-21 provides additional data on pipe sizes, roughness, and demands. The data file for this example is Campus Steam Distribution.P2K (Examples button – 6 Campus Facilities folder).. For the sake of simplicity all elevations are set at 400 feet. Baseline demands of 400 #/hr are located at each building. Analysis highlights include:

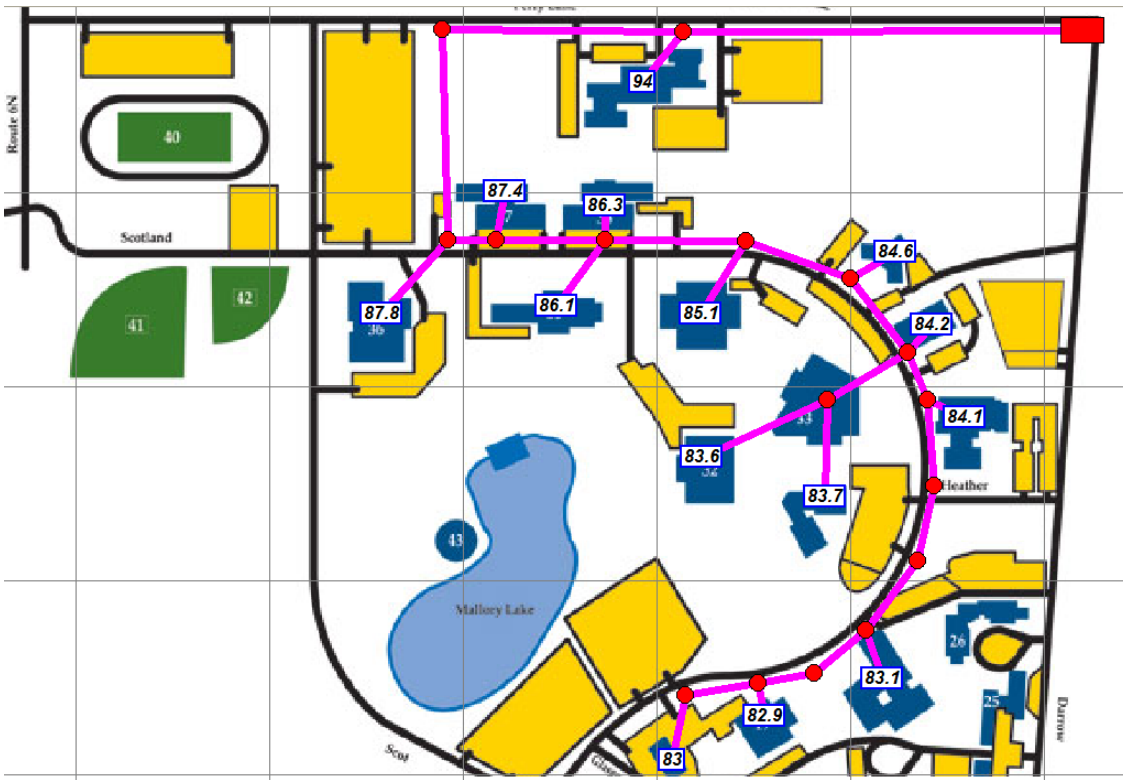
Saturated Steam Analysis:

- 1) plant provides saturated steam @ 100 psi**
- 2) saturated steam is distributed to all buildings**
- 3) properties of the saturated steam are determined using Steam Tables**
- 4) Load increases from low (400 #/hr) to high (800 #/hr)**

The model was analyzed for range of building loads (400 – 800 #/hr). Pressures at the buildings are shown in Figure CF-22 for the low and high loads. Figure CF-23 shows the pressures variations at several buildings for the range of loads (400 – 800 #/hr). This shows that the higher loads will not be feasible for all buildings because of low pressures.



Figure CF-21 Saturated Steam Distribution Model



Load = 400 #/hr



Load = 720 #/hr

Figure CF-22 Steam Distribution Model Results – Building Pressures

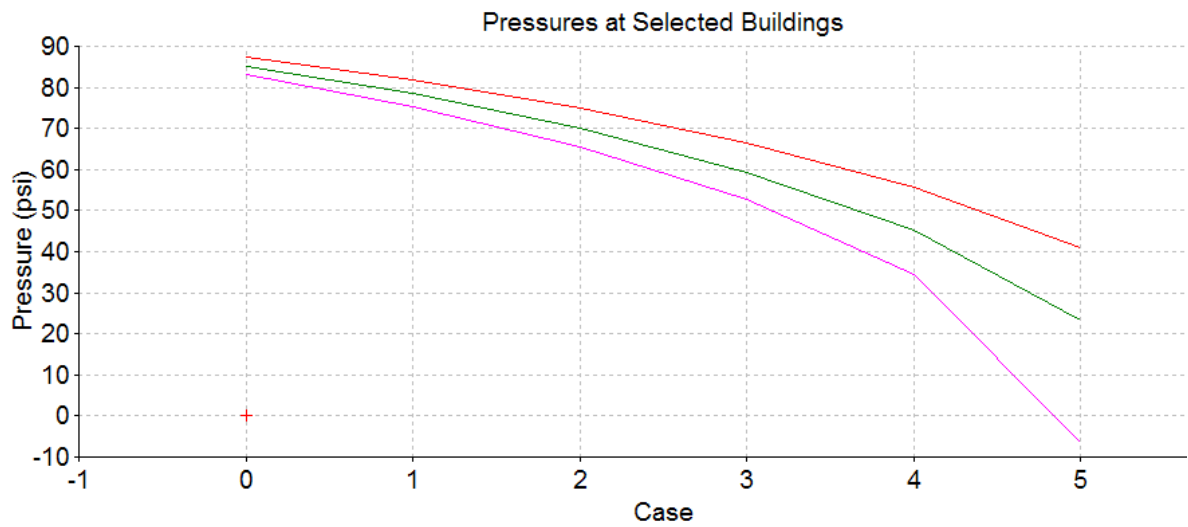


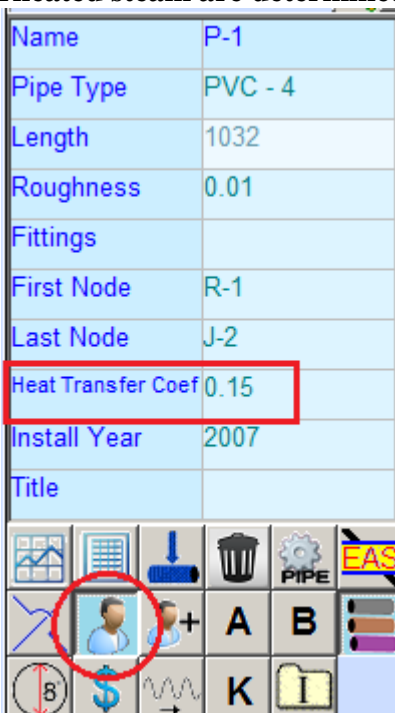
Figure CF-23 Pressures at Selected Buildings – load varies from 400 (case 0) to 800 #/hr (case 5)

6) Superheated Steam Distribution Model (Campus Superheated Steam.P2K)

Figure CF-21 also shows the layout of a campus Superheated Steam Distribution Model identical to the saturated steam model except for the steam properties. This system is supplied with superheated steam from a Steam Plant at 100 psi and 450 degrees F. Figure CF-21 also provides additional data on pipe sizes, roughness and demands. Additional details are provided in Figure CF-24. A feature of this model is that the heat loss and resulting temperature is calculated. A heat loss coefficient for each pipe (or a global value) along with the temperature at the steam plant is provided as input data. The data file for this example is Campus Superheated Steam.P2K (Examples button – 6 Campus Facilities folder).. Baseline demands of 400 #/hr are located at each building. Analysis highlights include:

Superheated Steam Analysis

- 1) plant provides superheated steam @ 100 psi and 450 degrees F
- 2) heat loss calculated using heat transfer coefficient = 0.15
- 3) select “Temperature Sensitive Analysis” to utilize “superheated steam”
- 4) properties of the superheated steam are determined using Steam Tables



Name	P-1
Pipe Type	PVC - 4
Length	1032
Roughness	0.01
Fittings	
First Node	R-1
Last Node	J-2
Heat Transfer Coef	0.15
Install Year	2007
Title	

KYnetic Heat Transfer Coefficient – User Data

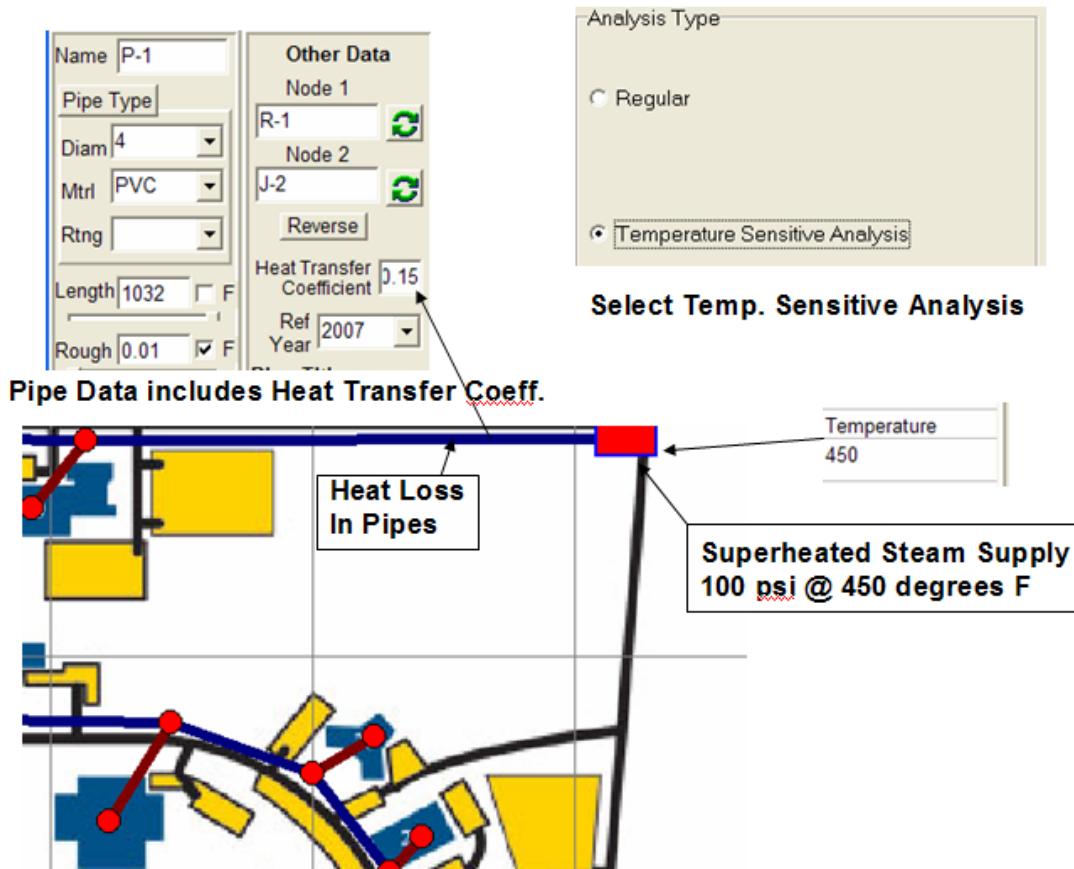


Figure CF-24 Superheated Steam Distribution Model Details

Tabulated results are shown in Figure CF-25 and include the densities, viscosities, and temperatures, all which vary throughout the distribution system. Figures CF-26-27b show the pressure, temperature, and superheat for a load of 400 #/hr at each building. Figure CF-28 compares the building pressures for the saturated and superheated analyses.

PIPE NO.	NODE #1	NODE #2	FLOW (LB/HR)	LOSS (PSI)	VELOCITY (FT/S)	DENSITY (LB/CU FT)	FRICTION FACTOR	AREA RATIO	HeatLoss (MBTU/hr)	Viscosity (ft ² /sec)
P-1	R-1	J-2	5999.999	7.37	87.89	0.21	0.013	0.091	142.53	3.19131E-07
P-10	J-10	J-11	1200	0.32	31.42	0.21	0.015	0.032	0.17	2.43388E-07
P-11	J-11	J-12	800	0.12	20.99	0.21	0.016	0.021	0.04	2.432383E-07
P-12	J-12	J-23	800	0.1	21.01	0.21	0.016	0.021	0.03	2.431624E-07
P-13	J-2	J-14	399.999	0.22	22.42	0.22	0.018	0.023	15.36	2.784139E-07
P-14	J-15	J-17	4800	1.31	71.05	0.21	0.013	0.073	29.92	2.618906E-07
P-15	J-15	J-16	400	0.17	23.22	0.21	0.018	0.024	6.18	2.561302E-07
P-16	J-17	J-5	4000	1.18	58.73	0.21	0.013	0.061	37.36	2.517983E-07
P-17	J-17	J-18	400	0.11	23.32	0.21	0.018	0.024	3.9	2.516106E-07
P-18	J-6	J-19	399.999	0.18	23.26	0.21	0.017	0.024	0.03	2.442545E-07

Node Results:

Junction No.	Node Title	Load (LB/HR)	Load M-BTU/HR	Enthalpy (BTU/LB)	Pressure (PSIA)	Pressure (PSIG)	Density (LB/ft ³)	Sat. Temp. (Deg. F)	Act. Temp. (Deg. F)	SuperHeat (Deg. F)
J-1		400	354.984	887.46	99.706	85.006	0.22	327.6	327.6	
J-10		0	0	0	94.941	80.241	0.21	324	324	
J-11		0	0	0	94.621	79.921	0.21	323.8	323.8	
J-12		0	0	0	94.5	79.8	0.21	323.7	323.7	
J-13		0	0	0	94.362	79.662	0.21	323.6	323.6	
J-14		400	363.244	908.112	107.093	92.393	0.23	332.8	336	3.1
J-15		0	0	0	99.392	84.692	0.21	327.3	354	26.6
J-16		400	355.109	887.773	99.216	84.516	0.22	327.2	327.2	
J-17		0	0	0	98.08	83.38	0.21	326.4	343	16.5
J-18		400	355.432	888.581	97.962	83.262	0.22	326.3	326.3	
J-19		400	355.956	889.89	95.952	81.252	0.21	324.8	324.8	

Figure CF-25 Superheated Steam Distribution Model – Tabulated Results

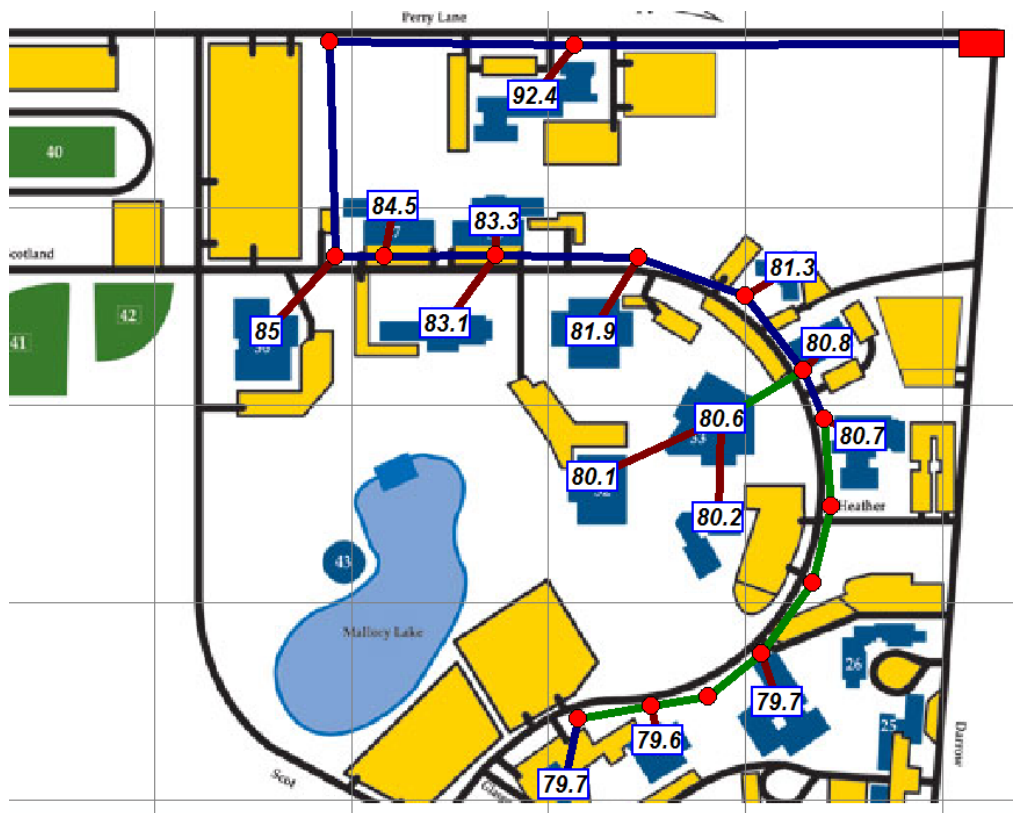


Figure CF-26 Superheated Steam Distribution Model – Pressures (400 #/hr)

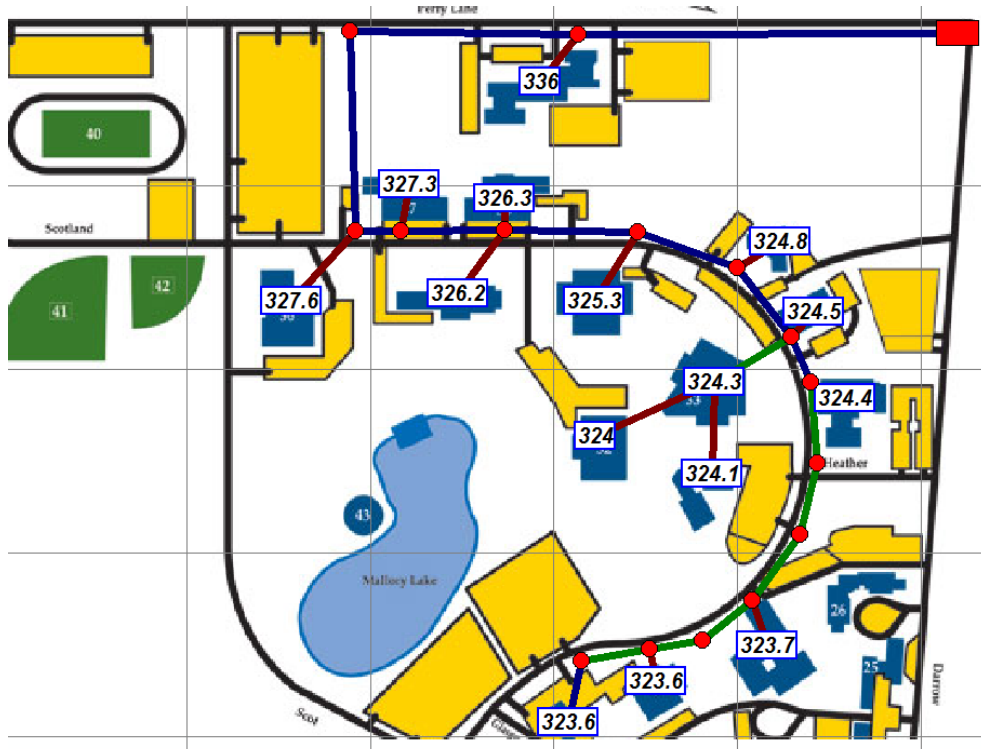


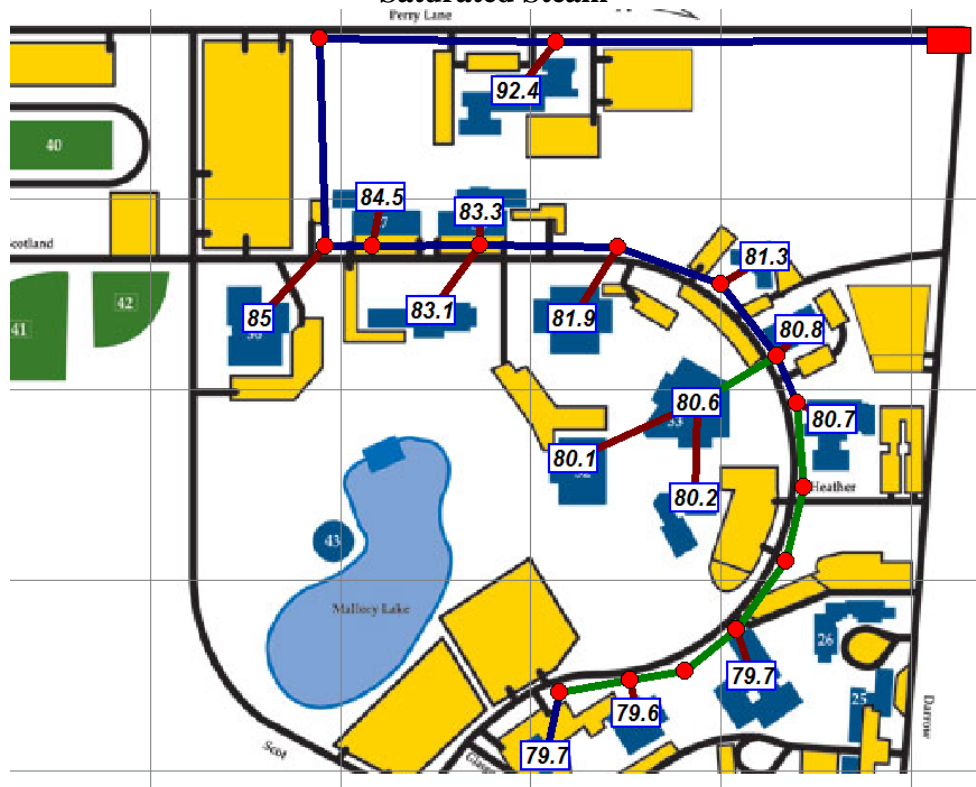
Figure CF-27a Superheated Steam Distribution – Building Temps (400 #/hr)



Figure CF-27b Superheated Steam Distribution – Superheat (400 #/hr)



Saturated Steam



Superheated Steam

Figure CF-28 Comparing Models – Pressures for 400 #/hr

Surge Demo Examples and Files

A demo for Surge illustrates the use of this powerful transient analysis program. The surge demo has the following limitations: 10 pipes, 1 Pump, 1 SDO, 1 Active Valve, 1000 feet total length and 6 inch pipe diameter. The purpose of the surge demo is to illustrate a range of capabilities with limits imposed so the demo software will not be used commercially. Although Surge can analyze large complex piping systems the demo consists of a single pipeline shown in Figure 1. A number of situations are modeled and analyzed:

- 1) Uncontrolled and controlled pump shutdown
- 2) Uncontrolled and controlled pump startup
- 3) Surge Protection (surge tank) for uncontrolled pump shutdown
- 4) Pump trip using full pump characteristics (pump file)

Data files for these examples are included in the program. In the Open File window, click the Examples button and browse the 7 Surge Demos folder. The appropriate data file for the various situations will be noted.

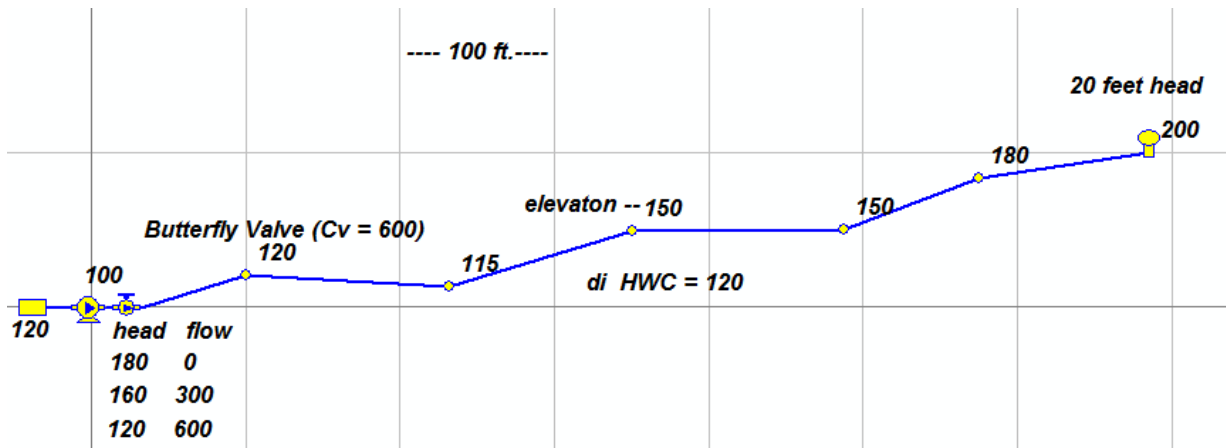


Figure 1 Pipeline Layout and Data

1) Uncontrolled and Controlled Pump Shutdown

demo shutdown no control.p2k

demo shutdown controlled.p2k

The pipeline layout and data is shown in Figure 1. The System Data is shown in Figure 2. Figure 3 shows the Pump and Active Valve data boxes. The main pipe lengths are scaled using the 100 foot grid lines. The wave speed for ductile iron (di) pipe is around 3900 ft/sec which is entered as the default. The pump station pipes are just 5 feet long and are not shown to scale. It is generally recommended to model short pipes with a reduced wave speed so the computational time will not be excessively small. Also a small amount of air entrainment in pump stations will considerably reduce wave speeds.

Once the data entry is completed the steady state analysis can be executed. The Surge has the option to run just the initial steady state analysis as shown in Figure 3. It is recommended that the initial steady state analysis is always run and the results carefully checked and verified. The steady state results are shown in Figure 4 (**Demo Shutdown No Control.P2K**). The pressures and flow is displayed on the pipe system model. Also the pump operation shown in the detailed report is shown. A steady state flow of 577 gpm with the pump providing 123.6 feet of head is calculated as shown. The detailed report of the data and results should be carefully reviewed before doing a transient analysis.

Surge System Data

Specific Gravity

User Units Units

Friction Equation

Kinematic Viscosity

Maximum # of Trials

Accuracy

Length Accuracy

Total Simulation Time

Cavitation Head

Time Step Increment

System Type

Additional Data

Demand Calculation

Fixed Demands

Exit Head

Do not calculate intrusion

Leakage Factor

Wave Speed

Attribute used for pipes "Wave Speed"

Default Wave Speed

Figure 2 System Data

Pump Curves

Name

Pump

Elevation

Sp Ratio

Pump Type

ID	Head	Flow	Eff%
1	180	0	0
	160	300	0
	120	600	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0

Node Type	Value
Name	Pump-1
Elevation	100
Title	
Parallel	Single
ID	1
Check Valve	<input checked="" type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0.1
CV Resistance	0.1
Bypass Resistance	1
Speed Ratio	1

Head	Flow
180	0
160	300
120	600
0	0
0	0
0	0
0	0
0	0

Pump Data

Node Type	Active Valve
Name	AV-1
Elevation	100
Title	
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0
CV Resistance	0
Bypass Resistance	0
Grade	-----
Direction	
On/Off	
Cv	600
Initial Ratio	1
Valve Type	Butterfly

Name AV-1

Active Valve

Elevation 100

Cv 100% 600

Init Ratio 1

Valve Type

Butterfly

Analysis Type

Surge

Surge with Force File

Steady State

Debug

Active Valve Data and Steady State Analysis

Figure 3 Pump and Active Valve Data and Setup for Steady State Analysis

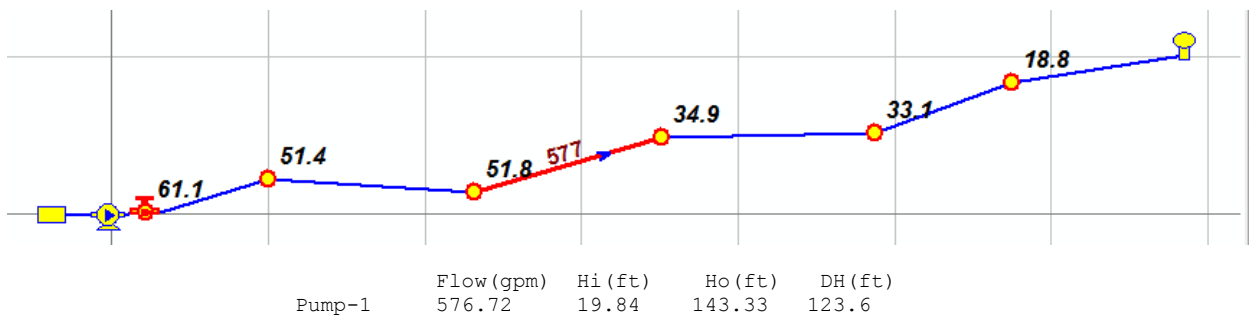


Figure 4 Steady State Results

Once the steady state results are verified then data (Change Data) to describe the transient is entered as shown in Figure 5. This data is entered in the Change Data box for the associated element as shown on the left for the pump (Pump-1) All Change Data can be

reviewed using in the upper toolbars or Setup/Defaults-Change Pattern screen as shown in Figure 5. The first screens show the setup for an uncontrolled shutdown where the pump ramps down from full speed (1) to zero in 3 seconds starting 2 seconds into the simulation. The 2 second delay prior to the initiation of the transient is specified to assure that the system is holding the steady state conditions prior to the initiation of the transient. It is recommended that this procedure always be followed as an additional check

on the model setup. The 2nd screen shows a controlled shutdown where the Butterfly Valve closes in 30 seconds and the pump speed ramps down in 10 seconds starting when the Butterfly valve is fully closed.

Results are shown in figure 6 which shows that the controlled shutdown (*Demo Shutdown Controlled.P2K*) produces a very small transient compared to the uncontrolled shutdown (*Demo Shutdown No Control.P2K*).

Figure 7 shows some screen shots from an animated profile module (Pipe2018). This module shows valve, pump, and surge protection devices actions and vapor cavity pocket formation and collapse.

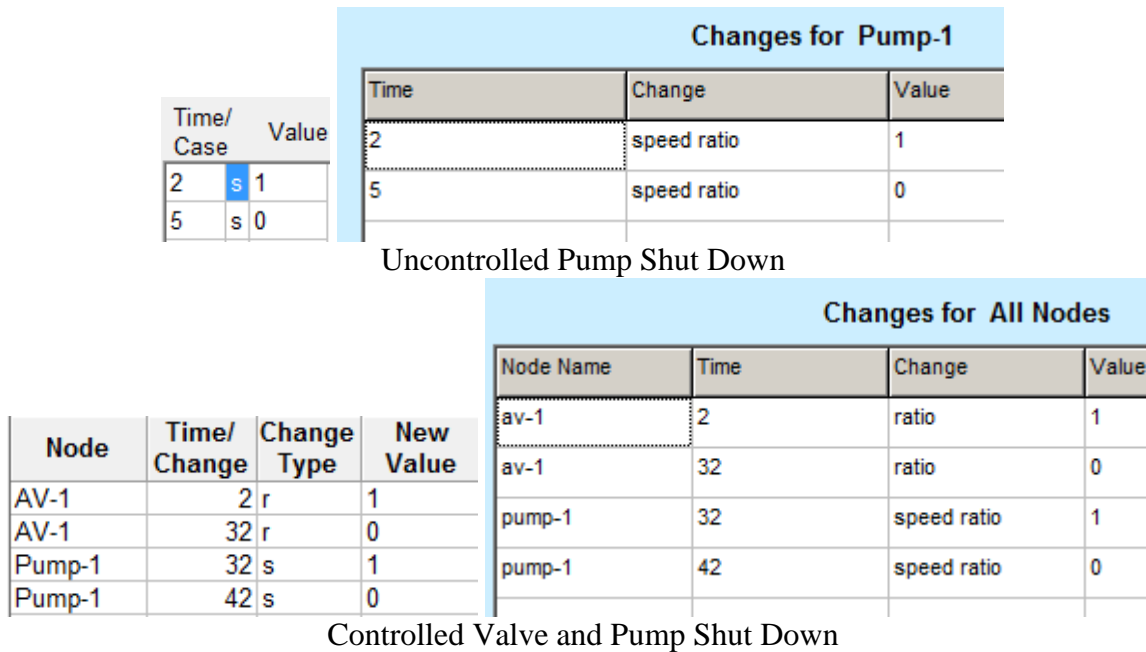


Figure 5 Change Data and Change Pattern Screens for an Uncontrolled and Controlled Shutdown

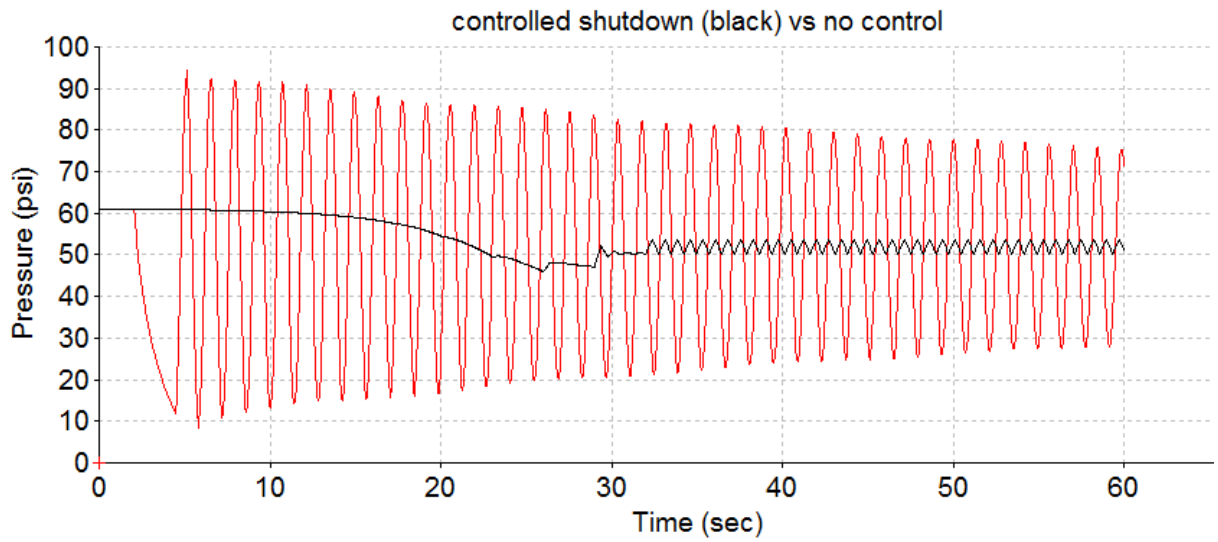
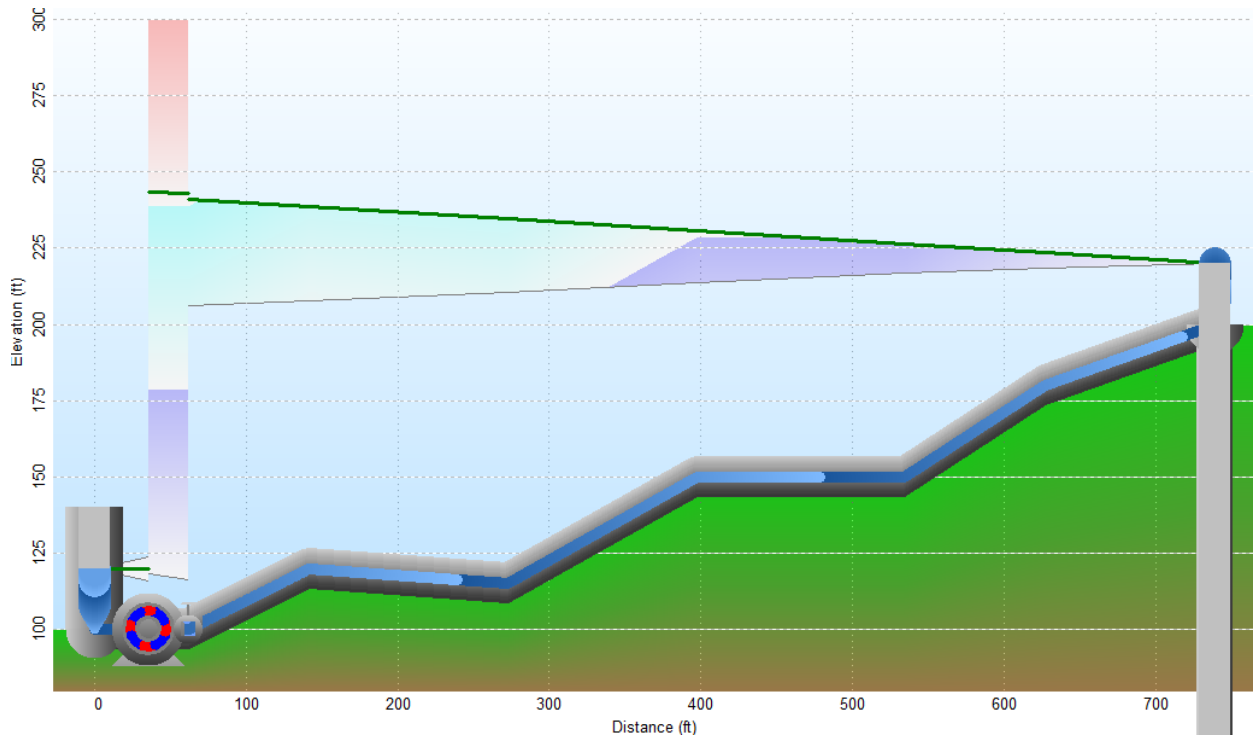


Figure 6 Results for an Uncontrolled and Controlled Shutdown



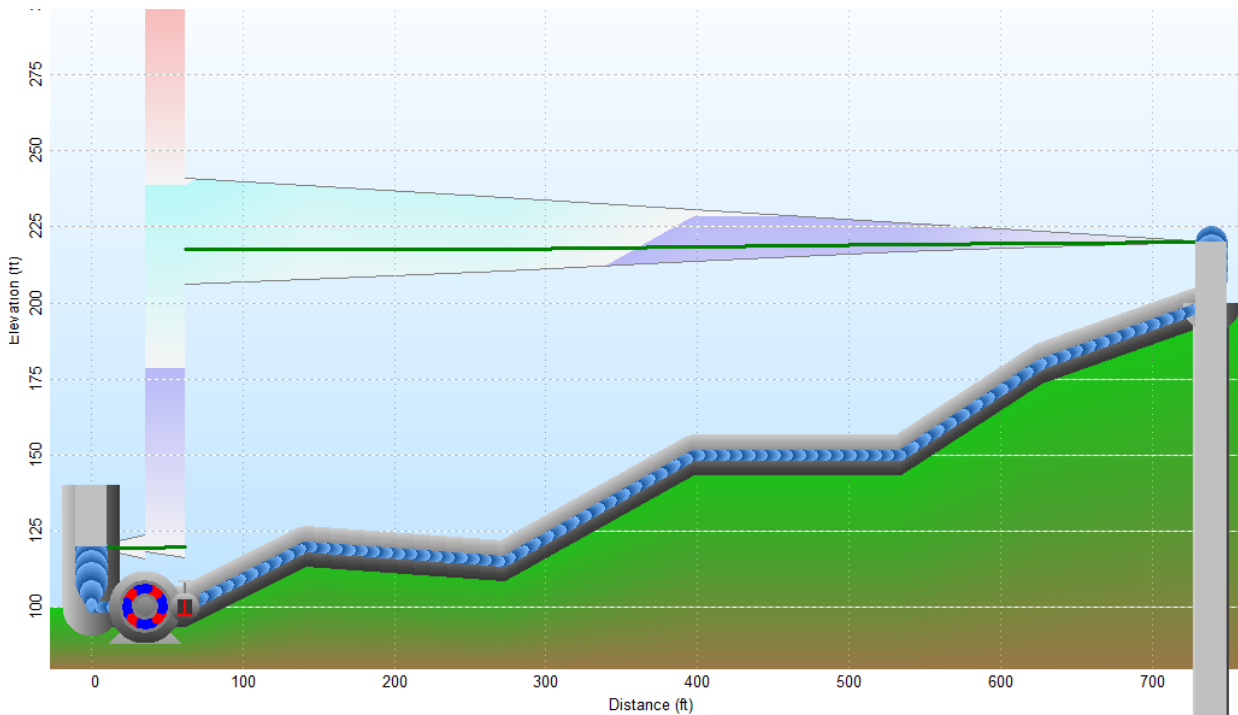


Figure 7 Animated Profile Displays of Results at beginning (top) and end (bottom) of the analysis

2) Uncontrolled and controlled pump startup

demo startup no control.p2k

demo startup controlled.p2k

Figure 8 shows the Change Pattern screens for an uncontrolled start up where the pump ramps up to full speed in 5 seconds. The screen on the right is for a controlled startup where the butterfly valve starts to open once the pump reaches full speed and opens in 20 seconds. Figure 9 shows the results for the uncontrolled (*Demo Startup No Control.P2K*) and the controlled (*Demo Startup Controlled.P2K*) files and confirms that the controlled startup transient is much smaller.

Changes for Pump-1			
Node	Time/Change	Change Type	New Value
Pump-1	2 s	0	
Pump-1	7 s	1	

Time	Change	Value
2	speed ratio	0
7	speed ratio	1

Startup No Control

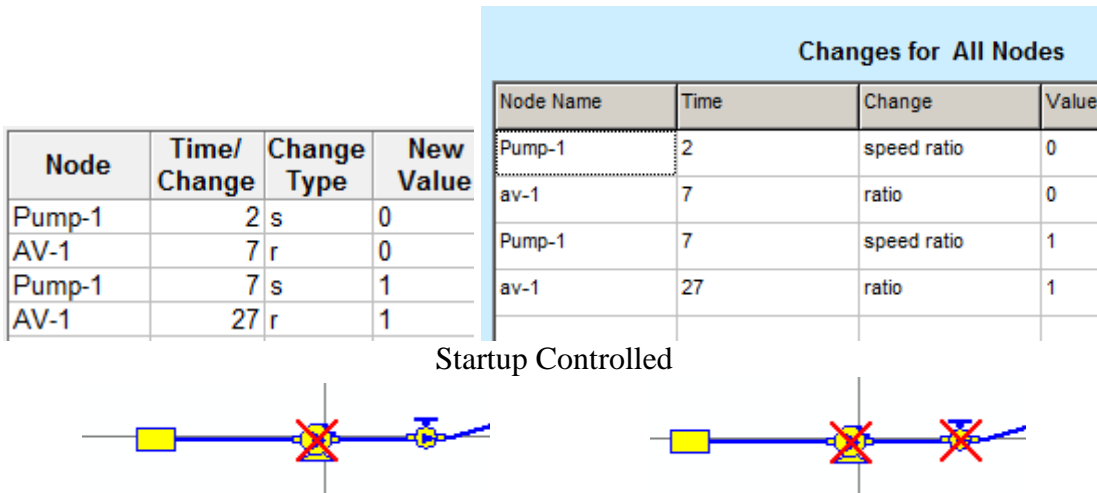


Figure 8 Change Pattern Screen for an Uncontrolled and Controlled Start Up

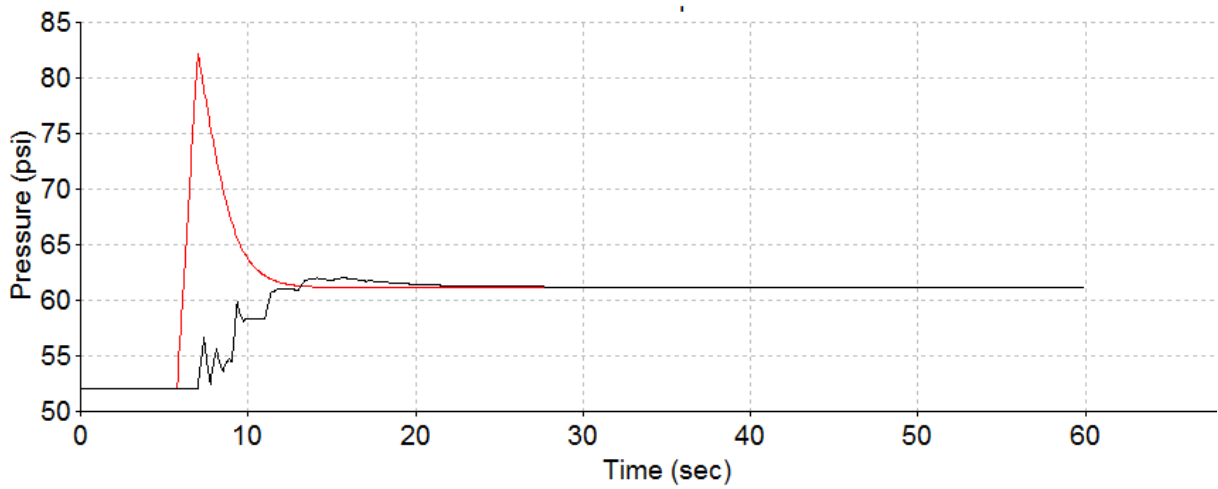


Figure 9 Results for an Uncontrolled and Controlled Start Up

3) Surge Protection (surge tank) for uncontrolled pump shutdown

demo surge tank.p2k

When a power outage occurs then an uncontrolled pump shutdown will occur (pump trip). When this happens, a surge protection device such as a surge tank may be required. This example illustrates modeling a surge tank for surge protection. The active valve is replaced by a surge tank (just select the active valve and select Closed Surge Tank from drop down list). The data for the surge tank is shown in Figure 10. Pipe2014: Surge has a tool to compute the resistance of the surge tank connection (Tools - Resistance Calculations/Connection to Tank). For a 6 inch connection a value of 1.0 is representative. The Surge Tank initial conditions (air volume, depth and tank diameter) are required input data. This surge tank is a 100 cubic foot (750 gallons) which is half full under the initial conditions. Figure 11 shows the pressure transient with and without the surge tank (*Demo Surge Tank.P2K*). To run the analysis w/o the surge tank just turn the tank OFF (ON/OFF button under Node Information).

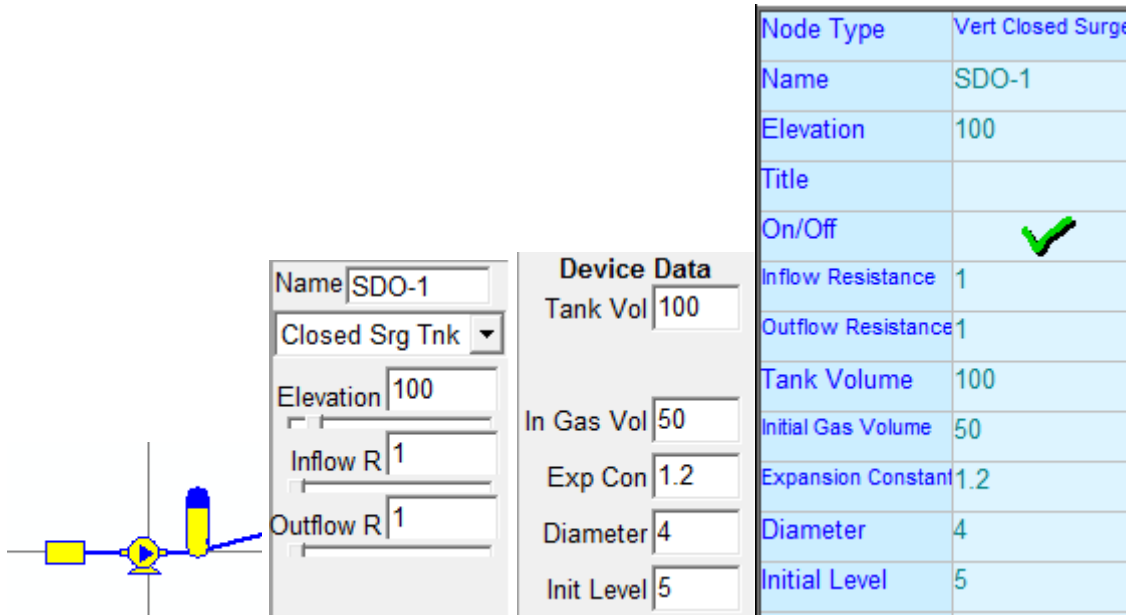


Figure 10 Surge Tank Data

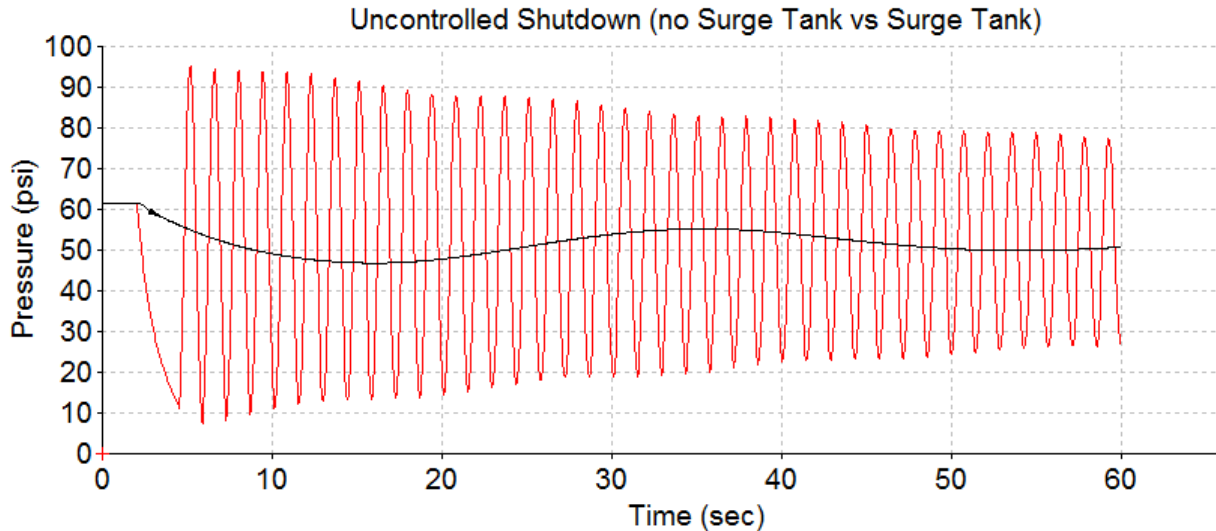


Figure 11 Results for an Uncontrolled Shutdown with and w/o Surge Tank

4) Pump trip using full pump characteristics (pump file)

demo pump trip.p2k

When modeling a power outage to a pump it is may be necessary to assume the ramp down time for the pump to go from full speed to zero. If the pump is equipped with a check valve which prevents reverse flow and turbining then making an assumption of 2-4 seconds will normally produce reasonable results. There is an option to utilize a Pump File which is based on four quadrant pump performance data. Thus, if the pump operates abnormally (turbining, etc.) a dynamic analysis can be carried out to determine the pump speed variation. A tool is available to determine which file to use (8 are available) and the appropriate inertia. It is recommended to use the operating pump head and flow to describe the pump when using the tool as shown in Figure 12. Using a pump head = 124 feet @ 576 gpm at 1000 rpm the tool suggests pump file 1 and an inertia around 10. Figure 12 shows the data boxes for defining a pump using a pump file. The Change Data can be used to specify a Pump Trip (at 2 seconds) as shown in Figure 12. Results presented in Figure 13 show that the transient using the pump file (***Demo Pump Trip.P2K***) is very similar to the one assuming a 3 second rundown. However, the use of a pump file to model a pump trip is recommended because the rundown time assumption is not required.

Pipe2000: Inertia - Specific Speed (Copy)

Units: English SI

Pump Speed N (rpm)

Flow Rate Q (gpm)

Pump Head h (ft)

Efficiency n (0 to 1)

Pump Power (HP)

INERTIA (lbft²)

Fairly Old Pumps

Small, light wt Pumps

Motor Inertia

Comb. Inertia (old pumps)

Comb. Inertia (small pumps)

Calculated Inertia is WR² (NOT GD²)

Specific Speed

Suggested Pump File

Node Type	Pump - File
Name	Pump-1
Elevation	100
Title	
Parallel	Single
Check Valve	<input type="checkbox"/>
Non-Reopening Che	<input checked="" type="checkbox"/>
Bypass Line	<input type="checkbox"/>
CV Time	0.1
CV Resistance	0.1
Efficiency %	75
Speed Ratio	1
Grade	----
File# (1-20)	1
Rated Head	124
Rated Flow	576
Rated Speed	1000
Inertia	10

Pump Inertia Tool and File Pump Data (KYnetic)

Name

Elevation

Sp Ratio

Effcnv%

Pump Type

Device Data

CV Time

CV Res

File (1-20)

Rated Hd

Rated Flw

Rated Spd

Inertia

Check Valve

NonReopen CV

File Pump Data (Classic)

Changes for Pump-1			
Time/Case	Value	Time	Change
2	t Trip	2	trip

Pump Trip Change Data

Figure 12 Pump File Tool, Pump Data and Change Data

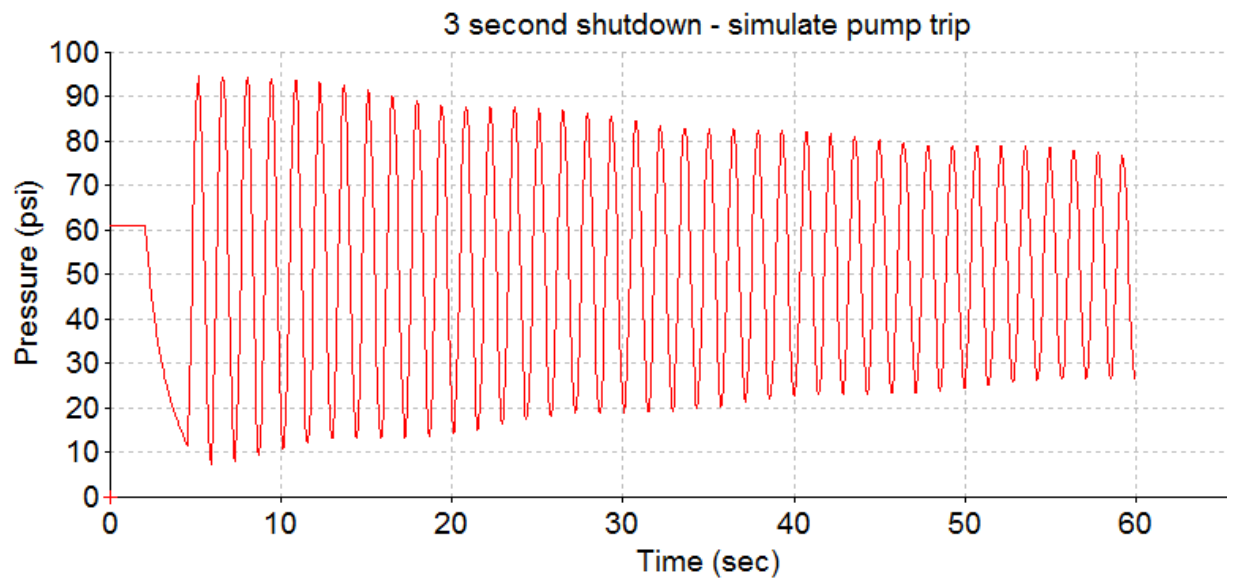
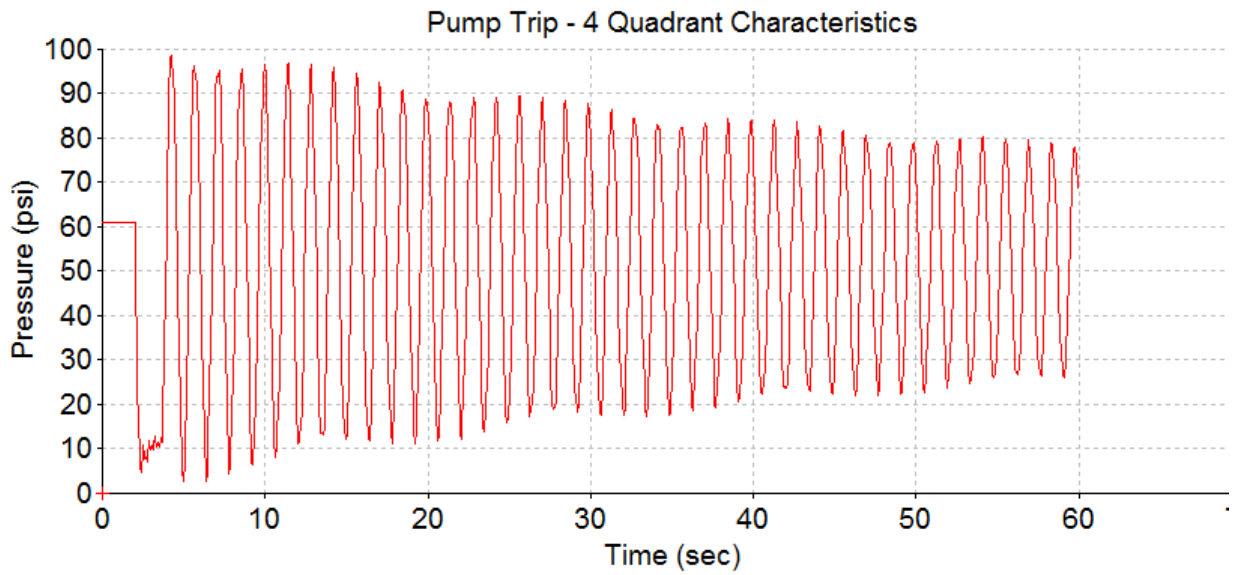


Figure 13 Results for an Pump Trip and an Uncontrolled 3 second Shutdown