FluidFlow

The Flow of Liquid via a Pump

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The flow of a Liquid via Pump

Problem

Water at 25°C is pumped from an open storage tank (0 barg) to an open overhead tank (0 barg) by means of a centrifugal pump. The piping system consists of a 15 m equivalent length of 6" SCH 40 steel pipe from the open storage tank to the pump suction; a 4" SCH 40 steel pipe follows the pump discharge for an equivalent length of 15 m to the tank. The open storage tank bottom is at an elevation of 2 m. The end of the discharge line is at an elevation of 10 m above grade. The centerline of the pump is 1 m above grade. If it is desired to maintain a flow of water of 100 m3/hr into the overhead storage tank. Determine the following:

- 1) Velocities in the pipes
- 2) Reynolds number in the pipes
- 3) Darcy friction factors
- 4) Friction loss in the pipes
- 5) Pump head
- 6) Pump differential pressure
- 7) NPSH available

Objective

Pumps are used to transfer liquids from the source with lower pressure to the sink with higher pressure. If the pump is not available, the liquid will move in the opposite direction due to pressure differences.

Pumps are also used to transfer liquids from the source at a lower elevation to the sink at a higher elevation.

In this example, you will build a model to illustrate the flow of liquid via a pump.

This example includes the following tasks:

- Task 1 Add the Boundaries, Pump, and Piping Components
- Task 2 Define the Boundaries, Fluid, Piping, and Pump
- Task 3 Select Results Unit Set
- Task 4 Calculate and Perform Hydraulic Analysis
- Task 5 Compare the FluidFlow Results to Hand Calculation



Task 1 – Add the Boundaries, Pump, and Piping Component

1. Start a new flowsheet by opening the FluidFlow software. The user interface will appear as shown below (Figure 1).

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loun	daries	s Qu	nctio	ns	Boos	ters	Ve	lves	C	ontr	ollers	s \(c	heck	Valv	es V	Gene	ral R	esista	nces	Size	Cha	nge	Relia	f De	vices	Ĥ	eat Er	xchar	ngen	5																						
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Figure 1: New flowsheet user interface.

2. Consider the boundary nodes to use for the system. Since we know the inlet and outlet pressure, we can use the *Known or Assigned Pressure* node available from the *Boundaries* tab on the *Component Palette* (Figure 2).

Pip	es Boundaries Junctions Boosters
	🚈 🛱 다 🥆 🖬 🧕
2	Known or Assigned Pressure

Figure 2: Known or Assigned Pressure Node.

3. Place two of these nodes (inlet & outlet) on the flowsheet by left mouse-clicking on the icon on the *Component Palette*. To place the node on the flowsheet we need to left mouse-click in the desired location (Figure 3).



1 '		•					•	2
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Figure 3: Known Pressure Nodes.

4. This represents our pipe boundaries. We can now add our fluid motive device by selecting the desired booster from the Component Palette. In this design case, let us select the centrifugal pump from the *Component Palette* (Figure 4).

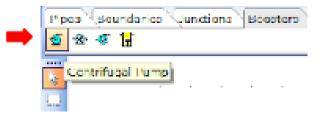


Figure 4: Centrifugal Pump Icon.

5. Place the centrifugal pump icon on the flowsheet by left mouse-clicking on the icon on the *Component Palette*. To place the node on the flowsheet, we need to left mouse-click in the desired location (Figure 5).

1					з .					2	
Ŧ					Ð					Ŧ	

Figure 5: Centrifugal Pump in the middle of the Known Pressure Nodes.

6. We can now connect the boundaries and centrifugal pump by selecting the desired pipe material from the *Component Palette*. In this design case, we know the pipe is a Schedule 40 steel pipe. Therefore, we need to select the Steel Pipe or Duct icon from the Component Palette (Figure 6).

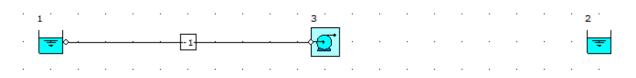
Pip	es Boundaries Junctions Boosters
/	////////////
 □	Steel Pipe or Duct

Figure 6: Steel Pipe of Duct Icon.

7. To connect the inlet boundary and centrifugal pump, left mouse-click directly over the inlet boundary node (node 1) and again, left mouse-click directly over the centrifugal pump suction

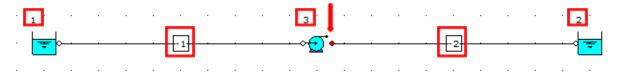


(node 3). Note, when you position the mouse selector above the boundary node and centrifugal pump on the flowsheet, you will see the selector change to a green "tick" symbol (\bigcirc). This indicates that the software is ready to connect our new node. The hydraulic model will appear as shown below (Figure 7):





8. To connect the centrifugal pump and outlet boundary, left mouse-click directly over the centrifugal pump discharge (node 3) and again, left mouse-click directly over the outlet boundary node (node 2).





Note: The RED dot on the centrifugal pump (Figure 8) indicates the discharge side.

9. At this stage, we will notice that the software automatically assigns a unique User Number (reference number) to each node placed on the flowsheet. All boundaries and fittings have positive User Numbers whereas all pipes have negative User Numbers. In Figure 8, we can see that the inlet boundary, outlet boundary, and centrifugal pump are assigned with User Numbers "1", "2", and "3", respectively. The suction and discharge pipes are assigned with User Numbers "-1" & "-2", respectively. Note, if these reference values have not appeared automatically, they may be toggled off. You can toggle these back on by selecting the buttons to the left of the flowsheet titled "Show or Hide Node Numbers" and "Show or Hide Pipe Numbers". The buttons appear as follows (Figure 9):

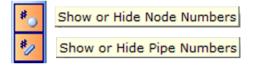


Figure 9: Show or Hide Node/Pipe Numbers buttons.

The automatic assignment of *User Numbers* helps us differentiate each of the nodes when we examine our systems – post calculation. This will become more apparent later.

^{10.} Save your flowsheet as **03-FF Liq via Pump.FF3**



Task 2 – Define the Boundaries, Fluid, Piping, and Pump

The next step is to edit the default data for each of the nodes placed on the flowsheet (Boundaries, Fluid, Piping, and Pump). Let us begin with the boundaries. We know the intended pressure units are in **barg** for both the inlet and outlet boundary. We can edit multiple nodes at once which will help speed up model development.

11. Left mouse-click on the inlet boundary (node 1) and whilst holding the SHIFT key, left mouse-click on the outlet boundary (node 2). You should now see both nodes highlighted on the flowsheet (Figure 10).

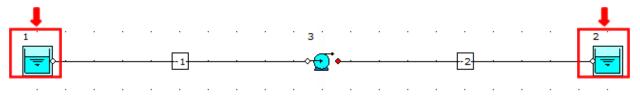


Figure 10: Highlighted Boundary Nodes.

12. We can now edit the data entry for both nodes at once from the Input Inspector on the *Data Palette* (Figure 11).

Data Palette 👃		Ф.
Messages Input	Results	Chart List Watch
Unique Name		
Status		On
Elevation		0
Elevation Unit		m
Pressure Model		Stagnation Pressure
Pressure		1
Pressure Unit		atm
Temperature		15
Temperature Unit		с
Fluid		water
Fluid Type		Newtonian/NN-NonSettling
Properties on Flows	sheet	Hide

Figure 11: Input Inspector.

13. In this case we need to change the *Pressure Unit* from the default *atm* setting to *barg*. Left mouse-click on the *Pressure Unit* field and you will see a drop-down arrow symbol appear on the right-hand side. Click on this symbol and a drop-down menu will appear showing the various units you can choose from. Select *barg* from the list (Figure 12). We have now successfully changed the pressure units for both nodes.



Data Polette	0
Mossoges Input Result	a Chart List Watch
Unique Name	
Status	On
Clevation	0
Elevation Unit	m
Pressure Model	Stagnotion Pressure
Pressure	1
Pressure Unit	atm 👻
Temperature	atm
Temperature Unit	bar a
Huid	om Fluid a
Fluid Type	om Fuid q ft Fluid a
Properties on Flowsheat	ft Fluid q
	ft Water a Y

Figure 12: Pressure Units.

14. We can now change the inlet elevation, pressure, and fluid temperature by selecting node 1. View the *Data Palette* and click the *Input Tab*. Enter the following specifications:

In this cell	Enter
Elevation	2
Pressure	0
Temperature	25

The Input Inspector on the *Data Palette* should now look like the screenshot given below (Figure 13).

Data Palette	Į.
Messages Input Results	Chart List Watch
Unique Name	
Status	On
Elevation	2
Elevation Unit	m
Pressure Model	Stagnation Pressure
Pressure	0
Pressure Unit	bar g
Temperature	25
Temperature Unit	С
Fluid	water
Fluid Type	Newtonian/NN-NonSettling
Properties on Flowsheet	Hide

Figure 13: Input Inspector at Node 1.

Note that we will keep the default water as our Fluid.



15. We can now change the outlet elevation and pressure by selecting node 2. View the *Data Palette* and click the *Input Tab*. Enter the specifications:

In this cell	Enter
Elevation	10
Pressure	0

The Input Inspector on the *Data Palette* should now look like the screenshot given below (Figure 14).

Data Palette	ф.
Messages Input Results	Chart List Watch
Unique Name	
Status	On
Elevation	10
Elevation Unit	m
Pressure Model	Stagnation Pressure
Pressure	0
Pressure Unit	bar g
Temperature	15
Temperature Unit	С
Fluid	water
Fluid Type	Newtonian/NN-NonSettling
Properties on Flowsheet	Hide

Figure 14: Input Inspector at Node 2.

For the temperature input, we don't need to change it to 25°C. Note that FluidFlow will use the operating conditions of the source fluid (node 1) in calculating the fluid properties such as density, viscosity, thermal conductivity, etc.

16. Let us now edit the default suction pipe data by selecting pipe number -1. You should now see that pipe number -1 is highlighted on the flowsheet (Figure 15).

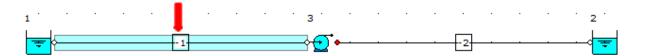


Figure 15: Highlighted Pipe "-1".

17. View the Data Palette and click the Input Tab. Enter the following specifications:

In this cell	Enter
Length	15



Nominal Size	6 inch
	8 111011

To change the default 2-inch size, left click on the field titled *Nominal Size* and a button with 3 dots will appear (Figure 16):

Data Palatte 🛛 🔍	
Mossages Input Reau	ts Chart List Watch
Unique Name	
Status	On
Length	15
Longth Unit	m
Coometry	Cylindrical
Use Database Size	Yes
Nominal Size	J inch
Classification	Schedule 40

Figure 16: Nominal Size with 3 dots button.

Click the button and a Set Pipe Dimension dialog box will appear (Figure 17):

Steel Pipe or Duct	
> 1/8 inch	
> 1/4 inch	
> 3/8 inch	
> 1/2 inch	
> · 3/4 inch	
> 1 inch	
> 1 1/4 inch	
> 1 1/2 inch	
✓ 2 inch	
B36.10M 1.65mm	
B36.10M 11.07mm	
B36.10M 2.11mm	
B36.10M 2.77mm	
B36.10M 3.18mm	
B36.10M 3.58mm	
- B36.10M 3.91mm	
- B36.10M 4.37mm	
B36.10M 4.78mm	
B36.10M 5.54mm	
B36.10M 6.35mm	
B36.10M 7.14mm	
- B36.10M 8.74mm	
Schedule 10	
Schedule 160	
Schedule 30	
Schedule 40	
- Schedule 5	
- Schedule 80	
STD	
···· XS	
XXS	
> 2 1/2 inch	
> · 3 inch	
> 3 1/2 inch	
> 4 inch	
> 5 inch	
> 6 inch	
> 8 inch	
> 10 inch	

Figure 17: Set Pipe Dimension Dialog Box.

This dialog box will allow us to access the pipe database (Figure 17). From the list of the available pipe sizes, click on the **6 inch** to view the various pipe classifications for this diameter. Select **Schedule 40** and click **OK** to complete this change (Figure 18).



Set Pipe Di	nension			
> 3 1/2	inch			
> 4 inc				
> 5 inc	1			
√ 6 inc				
	36.10M 10.97mm			
	36.10M 12.7mm			
	36.10M 14.27mm			
_	36.10M 15.88mm			
	36.10M 18.26mm			
	36.10M 19.05mm			
	36.10M 2.11mm			
_	36.10M 2.77mm			
	36.10M 21.95mm			
	36.10M 22.23mm			
	36.10M 3.18mm			
_	36.10M 3.4mm			
	36.10M 3.58mm			
	36.10M 3.96mm			
	36.10M 4.37mm			
_	36.10M 4.37mm			
_	36.10M 5.16mm			
	36.10M 5.56mm			
	36.10M 6.35mm			
	36.10M 7.11mm			
	36.10M 7.92mm			
	36.10M 8.74mm			
	36.10M 9.53mm			
-	checule 120			
	chedule 160			
	chedule 40			
	chedule 80			
S				
X				
X				
> · 8 inc				
> 10 in				
> 12 in				
> 14 in				
> 16 in				
> 18 in	sh	 		
		OK	Cancel	Help

Figure 18: Set Pipe Dimension Dialog Box.

18. The Input Inspector on the *Data Palette* should now look like the screenshot given below (Figure 19).

Data Palette		
Messages Input Results	Chart List Watch	
Unique Name		
Status	On	
Length	15	
Length Unit	m	
Geometry	Cylindrical	
Use Database Size	Yes	
Nominal Size	6 inch	
Classification	Schedule 40	
Friction Model	Moody	
Use Database Roughness	Yes	
Roughness Description	Clean or new	
Use Database Scaling	No	
Scaling (0 to 50%)	0	
Sizing Model	Economic Velocity	
Heat Loss Model	Ignore Heat Loss/Gain	
Draw Thickness [15]	1	
Draw Color	clBlack	
Properties on Flowsheet	Hide	



Figure 19: Input Inspector at Pipe Number "-1".

19. Let us now edit the default discharge pipe data by selecting pipe number -2. You should now see that pipe number -2 is highlighted on the flowsheet (Figure 20).

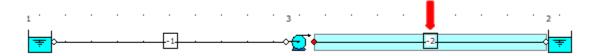


Figure 20: Highlighted Pipe "-2".

20. View the *Data Palette* and click the *Input Tab*. Enter the following specifications:

In this cell	Enter
Length	15
Nominal Size	4 inch

To change the default 2-inch size, left click on the field titled *Nominal Size* and a button with 3 dots will appear (Figure 21):

Data Palatte		Ģ
Messages Input Res	ults Chart List W	atch
Unique Name		
Status	On	
Length	15	
Longth Unit	m	
Coometry	Cylindrical	
Use Database Size	Yes	
Nominal Size	a inch	
Classification	Schedule 40	

Figure 21: Nominal Size with 3 dots button.

Click the button and a Set Pipe Dimension dialog box will appear (Figure 22):



✓ Steel Pipe or Duct	
> 1/8 inch	
> 1/4 inch	
> 3/8 inch	
> 1/2 inch	
> 3/4 inch	
> 1 inch	
> 1 1/4 inch	
> 1 1/2 inch	
✓ 2 inch	
- B36.10M 1.65mm	
B36.10M 11.07mm	
B36.10M 2.11mm	
B36.10M 2.77mm	
B36.10M 3.18mm	
B36.10M 3.58mm	
- B36.10M 4.37mm	
- B36.10M 4.78mm	
- B36.10M 5.54mm - B36.10M 6.35mm	
- B36.10M 0.35mm	
- B36.10M 8.74mm	
- Schedule 10	
- Schedule 160	
Schedule 30	
Schedule 40	
Schedule 5	
Schedule 80	
STD	
XS	
XXS	
> 2 1/2 inch	
> 3 inch	
> 3 1/2 inch	
> 4 inch	
> 5 inch	
> 6 inch	
> 8 inch	
> 10 inch	

Figure 22: Set Pipe Dimension Dialog Box.

This dialog box will allow us to access the pipe database (Figure 22). From the list of the available pipe sizes, click on the **4 inch** to view the various pipe classifications for this diameter. Select **Schedule 40** and click **OK** to complete this change (Figure 23).

XS	
XXS	
> 2 1/2 inch	
> 3 inch	
> 3 1/2 inch	
→ ✓ 4 inch	
B36.10M 11.13mm	
B36.10M 13.49mm	
B36.10M 17.12mm	
B36.10M 2.11mm	
B36.10M 2.77mm	
B36.10M 3.05mm	
B36.10M 3.18mm	
B36.10M 3.58mm	
B36.10M 3.96mm	
B36.10M 4.37mm	
B36.10M 4.78mm	
B36.10M 4.76mm	
- B36.10M 5.56mm	
B36.10M 5.56mm	
- B36.10M 6.35mm	
- B36.10M 7.14mm	
- B36.10M 7.92mm	
- B36.10M 8.56mm	
Schedule 120	
Schedule 120	
Schedule 40	
Schedule 80	
STD	
xs	
XXS	
> · 5 inch	
> 6 inch	
> · 8 inch	
> 10 inch	
> 12 inch	
> 14 inch	
> 16 inch	_
> 18 inch	
> 20 inch	
, Lo mon	



Figure 23: Set Pipe Dimension Dialog Box.

21. The Input Inspector on the *Data Palette* should now look like the screenshot given below (Figure 24).

Data Palette		
Messages Input Results Chart List Watch		
Unique Name		
Status	On	
Length	15	
Length Unit	m	
Geometry	Cylindrical	
Use Database Size	Yes	
Nominal Size	4 inch	
Classification	Schedule 40	
Friction Model	Moody	
Use Database Roughness	Yes	
Roughness Description	Clean or new	
Use Database Scaling	No	
Scaling (0 to 50%)	0	
Sizing Model	Economic Velocity	
Heat Loss Model	Ignore Heat Loss/Gain	
Draw Thickness [15]	1	
Draw Color	clBlack	
Properties on Flowsheet	Hide	

Figure 24: Input Inspector at Pipe Number "-2".

22. Let us now edit the default centrifugal pump data by selecting node 3. You should now see that node 3 is highlighted on the flowsheet (Figure 25).

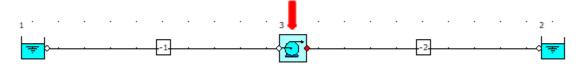


Figure 25: Highlighted Centrifugal Pump Node.

23. View the Data Palette and click the Input Tab. Enter the following specifications:

In this cell	Enter
Elevation	1
Automatically Size	On
Sizing Model	Size for Flow
Design Flow	100



24. The Input Inspector on the *Data Palette* should now look like the screenshot given below (Figure 26).

Data Palette		
Messages Input Results Chart List Watch		
Unique Name		
Status	On	
Elevation	1	
Elevation Unit	m	
Automatically Size	On	
Sizing Model	Size for Flow	
Design Flow	100	
Flow Unit	m3/h	
Discharge Pipe (RED)	-2	
Solids Derating	None	
Heat Loss Model	Ignore Heat Loss/Gain	
Properties on Flowsheet	Hide	

Figure 26: Input Inspector at Centrifugal Pump.

Note: The *Size for Flow* sizing model is used to maintain a flow rate of 100 m³/hr as specified in our problem.

25. Save your flowsheet.

Task 3 – Select Results Unit Set

In FluidFlow, it is possible to change the default results unit set used to display variables.

26. View the top portion of the user interface. The Units selector is on the middle portion (Figure 27):

🕫 Eile Edit View Database Options Tools Window Help	
: 🗋 🚰 🗸 🚰 🗄 💁 🖳 💭 🐰 🖙 🐁 ሕ 🔍 🭳 80% 🔹 Fine 💿 🔀 Calculate 📉 式 🗸 🧇 💂 System International 📑 🔹 🖬 🕄	è =
Pipes Boundaries Junctions Boosters Valves Controllers Check Valves General Resistances Size Change Relief Devices Heat Exchangers	
/////////////	



27. Click the drop-down menu to select a unit set. There are two default unit sets available: System International and US Basic (Figure 28).

0. T	System International	
× E .		
Chane	System International	kchancers \

Figure 28: Unit Selector Drop-Down Menu.



- 28. You can click and select the desired unit set for use, or even create your own custom unit set. In this example, we will use System International and create our own unit set.
- 29. We can change our units by right mouse-clicking on the *Results* tab followed by selecting *Results Units* from the drop-down menu (Figure 29).

Data Polette	۰
Messages 1(Input	Reau ta Chart Last Watch
User Number	-1
Element Type	Meccagec
Static Pressure	Recuito
Stagnation Pre 🤟	Chart
Criction Loss 🗸 🗸	Components List
Pressure Grad	Calculation Watch
Logs Correlatis	Data Palatte
In Huid Phase 🚁	Component Defaults 74
In Cross Soch	Ey By Options P6
In Static Press	Visible Results 78
In Velocity Pre	Recuit Unite P9
In Velocity	Calculation F2
In ataq, lemp	Elowsheet F3
In Static Temp	
In Density 🤣	Warning and Lints
In Viscosity	0.000 cP

Figure 29: Result Units.

30. Alternatively, you can select F9. This opens a new dialogue box per Figure 30.



Set Result Units ×												
General Gas Solids												
	Preferred Units											
<u>A</u> rea	mm2	~	•	1	F							
Composition Mass %			4	1	×							
Composition Volume %			4	3	۲							
<u>D</u> ensity	kg/m3	~	•	2	۲							
<u>F</u> low	kg/s	~	4	4	۲							
Flow <u>C</u> oefficient Cv,Kv	usgpm/psi	~	•	3	×							
Heat Transfer Coefficient	W/m2 C	~	•	5	F							
<u>L</u> ength	m	~	•	2	•	I						
NPSH	m Fluid	~	•	1	۲	I						
Pipe Si <u>z</u> e	mm	~	•	1	۲							
Power	Watt	~	•	1	۲							
Pressure/ <u>H</u> ead	Pa a	~	•	1	F							
Pressure/Head Drop	Pa	~	•	1	×	I						
Pressure Gradient	Pa/m	~	4	1	۲	I						
Specific Heat Capacity	J/kg C	•	2	×								
<u>T</u> emperature	С	•	1	•								
<u>V</u> elocity	m/s	•	2	•								
Viscosity	cP	~	•	3	۰							
	ОК	Cancel		Hel	p							

Figure 30: Set Result Units Dialogue Box.

31. Let us select the following units using the drop-down menu:

In this unit	Select
Flow	m³/h
Pressure/Head	bar g
Pressure/Head Drop	bar

32. The Set Result Units dialogue box should now look like the screenshot given below (Figure 31). Select **OK** to apply the changes.



General Gas Solids					
	Preferred Units		Dec	c. Pla	ices
<u>A</u> rea	mm2	\sim	•	1	•
Composition Mass %			•	1	•
Composition Volume %			•	3	•
<u>D</u> ensity	kg/m3	\sim	4	2	×
Elow	m3/h	¥	4	4	×
Flow <u>C</u> oefficient Cv,Kv	usgpm/psi	~	•	3	۲
Heat Transfer Coefficient	W/m2 C	~	•	5	۲
<u>L</u> ength	m	~	•	2	۲
NPSH	m Fluid	~	•	1	•
Pipe Size	mm	~	•	1	•
Power	Watt	×	4	1	Þ
Pressure/ <u>H</u> ead	bar g	~	•	4	•
Pressure/Head Drop	bar	v	4	3	×
Pressure Gradient	Pa/m	~	4	1	۲
Specific Heat Capacity	J/kg C	~	•	2	۲
Temperature	С	•	1	۲	
Velocity	m/s	•	2	•	
Viscosity	cP	~	•	3	•

Figure 31: Modified Set Result Units Dialogue Box.

33. Now that we have set the results unit, let us save the custom result unit set. Click the drop-down button at the right of the default unit set and select the Save Environment option (Figure 32).

o Filo I	Edit Vic	w D	otabo	ao (Option	19 I	ools	Win	cow	Help																
🗋 🎯 •	a 🖬	12 🖸	Ц.	<u>a</u> 1•	2 %	63		ħ €	Q (Q	80%	• Hino		. 2	Calo	u late		5.	۲	ε i ε	yptern	Intern	ational	-	-	11 II 🤣	
If pos (Bo	undarico	Qune	ctions	N BOR	ootoro	Va	shop	Cor	ntrolle	ra ^N (Cho	ck Vah	rcoN	Conc	aral R	coiota	ncos	- Siz	c Ch	ango	Įtalia	f Dovi	eco (H	icct E		Open Environment	
///	11	//	1	1	11		1	8																	Save Environment	
																								2	Component Defaults	F4
-				·		·						·		·		·								4	Excel Columns	F5
																								9	Hy By Options	F6
-																									Print Columna	F7
7																								e,	Visible Results	FB
-	-		-				-						-												Result Units	F9
+																										

Figure 32: Save Environment Option.

34. The Save Environment dialogue box will appear (Figure 33).



Save Envi	ironment			×
Folder:	C:\Users\Public\Documents\Flite	\FluidFlow3\Pref	erences\Defau	lt\3500
<u>F</u> ilename:				
Delete		Save	Cancel	Help

Figure 33: Save Environment Dialogue Box.

35. On the Filename: section type Custom Unit 1 and click Save (Figure 34).

😋 Save Env	ironment	×
Folder:	C:\Users\Public\Documents\Flite\FluidFlow3\Preferences\Default\3500	וכ
US Bas	n International.ffs ic.ffs	
<u>F</u> ilename:	Custom Unit 1	j
Delete	Save Cancel Help	

Figure 34: Modified Save Environment Dialogue Box.

36. Now that we have successfully added our custom unit, it is now available in the unit set drop-down menu (Figure 35). Let us now use **Custom Unit 1** as our preferred unit set for this example

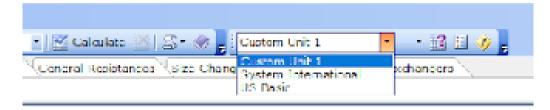


Figure 35: Unit Set Drop-Down Menu.

37. Save your flowsheet.



Task 4 – Calculate and Perform Hydraulic Analysis

Now that we have completed all the required inputs and customised the results unit set, we can now calculate the hydraulic model.

38. Calculate the model using the *Calculate* button located at the top of the flowsheet (Figure 36):

Eile Edit View Database Options Tools Window Help
🗄 🗋 😂 🗸 🔚 🕍 🗄 🙇 🖳 🖉 🔌 🐁 🖎 🔍 🔍 80% 🔹 Fine 🔹 🗖 Calculate 🔣 🖾 🗞 System International 🔹 🔹 😭 🗄 🚸 💂
Pipes Boundaries Junctions Boosters Valves Controllers Check Valves General Resistances Size Change Relief Devices Heat Exchangers
/////////////

Figure 36: Calculate Button.

39. Check the converged hydraulic model in the flowsheet. The blue arrowhead shows that the flow direction is from the source node 1 to the sink node 2. Also, check if the pipes and pump are highlighted in **RED**, indicating that we have a warning message associated with the pipe elements and pump (Figure 37).

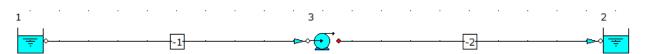


Figure 37: Converged Hydraulic Model

Note: Make sure that the **RED** Show or Hide Warnings Highlight button is selected in the *Flowsheet Toolbar* (Figure 38):



Figure 38: Show or Hide Warnings Highlight Button.

40. Select the *Messages* tab on the *Data Palette*, we can view all warnings for the model including a description of each (Figure 39). The converged hydraulic model has no warnings. Therefore, we can now proceed with the analysis of the results.

Data Polette	ą
Messages (Input (Results (Chart (List (Watch)	
Ucscription	

Figure 39: Warning Messages Tab.



Note: Warnings are enunciated by the software automatically to help the user eliminate any unwanted operating conditions and to prompt the user to develop a more efficient system design. Warnings should always be reviewed and considered by the engineer. You can evaluate and choose to ignore warnings if you wish.

41. Left-click the pipe number -1 and select the *Results* tab on the *Data Palette*. We can see all the calculated values for this pipe. Figure 40 provides an overview of these results.

	Data Palette 🔶		Д,	
	Messages Input Results	Chart List W	/atch	
	User Number	-1		
	Flow	100.0004	m3/h	
	Friction Loss	0.019	bar	
	Pressure Gradient	124.8	Pa/m	
	Loss Correlation	Darcy		
	Economic Velocity	1.26	m/s	Suggested Economic Dire (
	Exact Economic Size	167.9	mm	- Suggested Economic Pipe Ø.
The "In" values	Size	154.1	mm	- Actual I.D. of 6" Sch. 40 Pipe.
represent the calculated	In Stagnation Pressure	0.0000	bar g	
	In Static Pressure	-0.0111	bar g	
conditions at the	In Velocity	1.49	m/s	
pipe Inlet.	In Stag. Temperature	25.0	С	
	In Static Temperature	25.0	С	
The "Out" values	Out Stagnation Pressure	0.0791	bar g	
represent the calculated	Out Static Pressure	0.0680	bar g	
conditions at the	Out Velocity	1.49	m/s	
pipe Outlet.	Out Stag. Temperature	25.0	С	
pipe ennen	Out Static Temperature	25.0	С	
	Composition %	water (m)	100.0%	
		water (v)	100.000%	
	Reynolds No	257094.3		
	Friction Factor	0.017393		

Figure 40: Calculated Results for Pipe "-1".

42. Left-click the pipe number -2 and select the *Results* tab on the *Data Palette*. We can see all the calculated values for this pipe. Figure 41 provides an overview of these results.

	Data Palette 😽		Ļ	
	Messages Input Results	Chart List	Watch	
	User Number	-2		
	Flow	100.0000	m3/h	
	Friction Loss	0.149	bar	
	Pressure Gradient	993.1	Pa/m	
	Loss Correlation	Darcy		
	Economic Velocity	1.26	m/s	Successful Factoria Direct
	Exact Economic Size	167.9	mm	- Suggested Economic Pipe Ø.
	Size	102.3	mm	- Actual I.D. of 4" Sch. 40 Pipe.
The "In" values	In Stagnation Pressure	1.0290	bar g	
represent the calculated	In Static Pressure	0.9720	bar g	
conditions at the	In Velocity	3.38	m/s	
pipe Inlet.	In Stag. Temperature	25.0	С	
	In Static Temperature	25.0	С	
The "Out" values	Out Stagnation Pressure	0.0000	bar g	
represent the calculated	Out Static Pressure	-0.0569	bar g	
conditions at the	Out Velocity	3.38	m/s	
pipe Outlet.	Out Stag. Temperature	25.0	С	
pipe outlet.	Out Static Temperature	25.0	С	
	Composition %	water (m)	100.0%	
		water (v)	100.000%	
	Reynolds No	387302.2		
	Friction Factor	0.017842		



Figure 41: Calculated Results for Pipe "-2".

43. Warnings are enunciated based on the settings defined in *Warnings & Hints*. You can view these set-points by selecting; Options | Warnings & Hints or alternatively, select the *Warnings & Hints* icon at the top of the flowsheet.

Warning & Hints icon:

Since we are modeling a liquid system, we are only interested in the Liquid Limits (Figure 42).

1in. Pipe Velocity 1ax. Pipe Velocity	0.2	
Max. Pipe velocity Velocity	4 m/s	
Min. Opening Control Valv	e (%) 20	
Max. Opening Control Valv	re (%) 75	

Figure 42: Warning and Hints: Liquid Limits.

- 44. As we can see in Figures 40 and 41, the actual flowing velocity of the liquid in pipes "-1" and "-2" are 1.49 m/s and 3.38 m/s, respectively. The velocities are within the 0.2 4 m/s range for the minimum and maximum pipe velocity (Figure 42). The high-velocity warning is enunciated once the actual flowing velocity is higher than the maximum velocity level set in our warnings (4 m/s See Figure 42).
- 45. FluidFlow automatically calculates an *Economic Velocity* and associated *Exact Economic Size* for each pipe in the model. These results can be viewed on the *Results* tab (Figure 40 and 41) and are provided as a suggestion in order to help develop an efficient system design. Note, it is down to the engineer's discretion as to whether or not the actual pipe size needs to be changed to be more in line with that suggested by the software. Therefore, the results for *Economic Velocity* and associated *Exact Economic Size* are suggested values only and do not have any effect on the overall operating conditions for the system.
- 46. Left-click the centrifugal pump (node 3) and select the *Results* tab on the *Data Palette*. We can see the calculated values for this pump. Figure 43 provides an overview of these results.



Data Palette		ф.
Messages Input Results	Chart List	Watch
User Number	3	
Duty Flow	100.0043	m3/h
Duty Pressure Rise	0.950	bar
Duty NPSH Available	10.8	m Fluid
In Stagnation Pressure	0.0791	bar g
In Static Pressure	0.0680	bar g
In Velocity	1.49	m/s
In Stag. Temperature	25.0	С
In Static Temperature	25.0	С
Out Stagnation Pressure	1.0290	bar g
Out Static Pressure	0.9720	bar g
Out Velocity	3.38	m/s
Out Stag. Temperature	25.0	С
Out Static Temperature	25.0	С
Composition %	water (m)	100.0%
	water (v)	100.000%

Figure 43: Calculated	Results	for Pump.
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Based on our design flow rate and system configuration, the pump will have a duty pressure rise (differential pressure) of **0.950 bar** or **95000 Pa**. The NPSHa is calculated as **10.8 m fluid**. If we wished to view the duty pressure rise using m fluid (head units), we can simply, right mouse-click on the *Results* tab and select *Results Units*. Change the field for *Pressure/Head Drop* to m Fluid and set the desired decimal point position (Figure 44).

General Gas Solids									
	Preferred Units								
Area	mm2	~	•	1	F				
Composition Mass %			•	1	F				
Composition Volume %			•	3	F				
Density	kg/m3	~	•	2	•				
<u>F</u> low	m3/h	~	•	4	×				
Flow <u>C</u> oefficient Cv,Kv	usgpm/psi	~	•	3	•				
Heat Transfer Coefficient	W/m2 C	~	•	5	×				
<u>L</u> ength	m	~	•	2	۲				
NPSH	m Fluid	~	•	1	۲				
Pipe Si <u>z</u> e	mm	~	•	1	×				
Power	Watt	~	•	1	×				
Pressure/ <u>H</u> ead	bar g	~	•	4	×.				
Pressure/Head Drop	m Eluid	~	4	3	×.				
Pressure Gradient	Pa/m	~	•	1	F				
Specific Heat Capacity	J/kg C	~	•	2	۲				
Temperature	С	~	•	1	×				
<u>V</u> elocity	m/s	~	•	2	×				
V <u>i</u> scosity	cP	~	•	3	•				
	ОК	Cancel	1	Hel	p				

Figure 44: Modified Set Result Units Dialogue Box.

In this case, the duty pressure rise is **9.7 m Fluid** (Figure 45). We know this to be true since $\Delta H = \Delta P/\rho^*g$ ($\Delta H = 95000/(997.09^*9.80665) = 9.7$ m Fluid).



Data Palette		Ļ
Messages Input Results	Chart List V	Watch
User Number	3	
Duty Flow	100.0043	m3/h
Duty Pressure Rise	9.715	m Fluid
Duty NPSH Available	10.8	m Fluid
In Stagnation Pressure	0.0791	bar g
In Static Pressure	0.0680	bar g
In Velocity	1.49	m/s
In Stag. Temperature	25.0	С
In Static Temperature	25.0	С
Out Stagnation Pressure	1.0290	bar g
Out Static Pressure	0.9720	bar g
Out Velocity	3.38	m/s
Out Stag. Temperature	25.0	С
Out Static Temperature	25.0	С
Composition %	water (m)	100.0%
	water (v)	100.000%

Figure 45: Modified Duty Pressure Rise Unit.

47. To answer the problem in this example, the following required parameters are also calculated by FluidFlow:

Parameter	Pipe "-1"	Pipe "-2"
Friction Loss	0.019 bar	0.149 bar
Reynolds Number	257094	387302
Darcy Friction Factor	0.0174	0.0178

48. Note that we can improve the presentation of our model by selecting the pipes "-1" and "-2" and changing the *Draw Thickness* and *Draw Color* from the Input Inspector. We have set the *Draw Thickness* to **3** and *Draw Color* to **cIRed** (Figure 46).



Data Palette	д
Messages Input Results	Chart List Watch
Unique Name	
Status	On
Length	15
Length Unit	m
Geometry	Cylindrical
Use Database Size	Yes
Nominal Size	6 inch
Classification	Schedule 40
Friction Model	Moody
Use Database Roughness	Yes
Roughness Description	Clean or new
Use Database Scaling	No
Scaling (0 to 50%)	0
Sizing Model	Economic Velocity
Heat Loss Model	Ignore Heat Loss/Gain
Draw Thickness [15]	3
Draw Color	elRed
Properties on Flowsheet	Hide

Figure 46: Modified Draw Thickness and Draw Color.

49. The hydraulic model should now look like the screenshot given below (Figure 47).

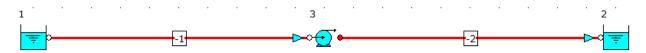


Figure 47: Hydraulic Model with Modified Draw Thickness and Draw Color.

50. Now let us show the properties of the boundaries. Left mouse-click on the inlet boundary (node 1) and whilst holding the SHIFT key, left mouse-click on the outlet boundary (node 2), and from the *Input Inspector*, change the field titled *Properties on Flowsheet* from *Hide* to *Show* (Figure 48).

Data Palette	Д
Messages Input Results	Chart List Watch
Unique Name	
Status	On
Elevation	10
Elevation Unit	m
Pressure Model	Stagnation Pressure
Pressure	0
Pressure Unit	bar g
Temperature	15
Temperature Unit	С
Fluid	water
Eluid Type	Newtonian/NN-NonSettling
Properties on Flowsheet	Show 👻
Alignment	Bottom
Font	Verdana,9,clWindowText,[]
Properties	

Figure 48: Show Properties on Flowsheet.

51. Now we will select the field titled *Properties* from the Input list. An *Element Properties* dialogue box will appear (Figure 49):



Element Properties			;
V Input			
Retained 100Mesh (.149mm)			
%Retained 200Mesh (.074mm)			
%Retained 20Mesh (.833mm)			
Retained 325Mesh (.043mm)			
Retained 35Mesh (.417mm)			
Retained 60Mesh (.25mm)			
Retained 625Mesh (.02mm)			
Concentration defined by			
d50 mean diameter			
- d50/d85 Size Unit			
d85 (85% of mass finer)			
- Z Elevation			
- Elevation Unit			
Flow Defined By			
- 🗹 Fluid			
🗌 Fluid Type			
- Mix Type			
Pressure			
Pressure Model			
- Pressure Unit			
Quality (01)			
- Solids			
Solids Concentration %			
- Status			
Temperature			
Temperature Unit			
Unique Name			
Use Size Distribution Data			
Wt% oven dry concentration			
✓ ✓ Results			
Calculated Quality (01)			~
Composition Mass %			•
		Select All	Clear All
	ок	Cancel	Help
	UN	Cancel	neip

Figure 49: Element Properties Dialogue Box.

52. Place a checkmark in the box for the following parameters and click **OK**:

Element Properties	
Input	Results
Elevation	Density
Fluid	Temperature
Pressure	Viscosity

53. The hydraulic model should now look like the screenshot given below (Figure 50).

1			•			3						2	
,		-1			~	.			-2			e 🚎 🕐	
Fluid	water											Fluid	water
Pressure	0 bar g											Pressure	0 bar g
Elevation	2 m											Elevation	10 m
Viscosity	0.890 cP											Viscosity	0.890 cP
Temperature	25.0 C											Temperature	25.0 C
Density	997.05 kg/m3											Density	997.05 kg/m3

Figure 50: Hydraulic Model with Inlet and Outlet Boundary Properties.



54. Now let us show the properties of the pipes. Left mouse-click on the pipe number "-1" and whilst holding the SHIFT key, left mouse-click on the pipe number "-2" and from the *Input Inspector*, change the field titled *Properties on Flowsheet* from *Hide* to *Show* and *Alignment* from *Bottom* to *Top* (Figure 51).

Data Palette 🎝					
Messages Input Results	Chart List Watch				
Unique Name					
Status	On				
Length	15				
Length Unit	m				
Geometry	Cylindrical				
Use Database Size	Yes				
Nominal Size	6 inch				
Classification	Schedule 40				
Friction Model	Moody				
Use Database Roughness	Yes				
Roughness Description	Clean or new				
Use Database Scaling	No				
Scaling (0 to 50%)	0				
Sizing Model	Economic Velocity				
Heat Loss Model	Ignore Heat Loss/Gain				
Draw Thickness [15]	3				
Draw Color	clRed				
Properties on Flowsheet	Show				
Alignment	Тор				
Font	Verdana,9,clWindowText,[]				
Properties					

Figure 51: Show Properties on Flowsheet.

55. Now we will select the field titled *Properties* from the Input list. An *Element Properties* dialogue box will appear (Figure 52):



2 Element Properties			>
> Input			^
✓ ☐ Results			
Calculated T Type			
- Composition Mass %			
Cvd Deposition Velocity			
Deposition Velocity			
- Economic Velocity			
Element Type			
- Exact Economic Size			
- Exact Pressure Gradient Size			
Exact Velocity Size			
Fines, Xf			
Flow			
Flow at NTP			
Flow at STP			
Fluid Shear Rate (in s-1)			
Friction Factor			
- Friction Loss			
- Fully Stratified, Xs			
Heat Transferred			
Heterogeneous, Xh			
In Cross Section Flow Area			
In Density			
In Fluid Phase			
In Gas Superficial Velocity			
In Lig Superficial Velocity			
In Mach Number			
In Piezometric Pressure			
In Specific Heat Capacity			
In Stag. Temperature			
In Stagnation Pressure			
In Static Pressure			
In Static Temperature			~
		Select All	Clear All
	ОК	Cancel	Help
	OK	Cancer	neip

Figure 52: Element Properties Dialogue Box.

56. Place a checkmark in the box for the following parameters and click $\ensuremath{\text{OK}}$:

Element Properties	
Input	Results
Length Nominal Size	Flow Friction Factor Friction Loss In Density In Velocity In Viscosity Out Density Out Velocity Out Viscosity Reynolds No Size Stagnation Pressure Loss Static Pressure Loss



	Length		15 m					Lengt	h			15 m]					
	Nominal Size		6 inch		•			Nomin	al Size	9		4 inch		j :			•		•
[Size		154.1	mm				Size				102.3 n	nm]					
	Friction Loss		0.019	bar	· ·			Frictio	n Loss	;		0.149 b	ar	· ·		•			
	Friction Factor		0.0173	93				Frictio	n Fact	or		0.0178	42						
· · ·	Flow		100.00	04 m3/h	· ·			Flow				100.00	00 m3/h	· ·				•	
	Static Pressure L	OSS	-0.079	bar				Static	Press	ure Lo	SS	1.029 b	ar						
	Stagnation Press	sure Loss	-0.079	bar	· ·			Stagn	ation I	Pressu	ure Loss	1.029 b	ar	· ·					
	Out Viscosity		0.890	сP				Out Vi	scosit	y		0.890 c	P						
	Out Velocity		1.49 m	/s	· ·			Out Ve	elocity			3.38 m/	s	· .	•		•		•
	Out Density		997.05	i kg/m3				Out D	ensity			997.05	kg/m3						
	In Density		997.05	i kg/m3	· ·			In Der	nsity			997.09	kg/m3	· ·					
	In Velocity		1.49 m	/s				In Velo	ocity			3.38 m/	s						
	In Viscosity		0.890	сP	· ·	3		In Vise	cosity			0.890 c	Р	· .	<u>.</u>				
1	Reynolds No		25709	4.3	1	3		Reyno	lds No)		387302	.2	1	2				
		-1				°€	•				-2				• -	•			
Fluid	water														Flui	d	wate	er	
Pressure	0 bar g														Pre	ssure	0 ba	rg	
Elevation	2 m														Elev	ation	10 m	ı	
Viscosity	0.890 cP														Viso	osity	0.89	0 cP	
Temperature	25.0 C														Tem	perature	25.0	С	
Density	997.05 kg/m3														Der	sitv	997.	05 kc	1/m3

57. The hydraulic model should now look like the screenshot given below (Figure 53).

Figure 53: Hydraulic Model with Pipe Properties.

58. Now let us show the properties of the pump. Left mouse-click on the pump (node 3) and from the *Input Inspector*, change the field titled *Properties on Flowsheet* from *Hide* to *Show* (Figure 54).

Data Palette 🏨						
Messages Input Results Chart List Watch						
Unique Name						
Status	On					
Elevation	1					
Elevation Unit	m					
Automatically Size	On					
Sizing Model	Size for Flow					
Design Flow	100					
Flow Unit	m3/h					
Discharge Pipe (RED)	-2					
Solids Derating	None					
Heat Loss Model	Ignore Heat Loss/Gain					
Properties on Flowsheet	Show 👻					
Alignment	Bottom					
Font	Verdana,9,clWindowText,[]					
Properties						

Figure 54: Show Properties on Flowsheet.

59. Now we will select the field titled *Properties* from the Input list. An *Element Properties* dialogue box will appear (Figure 55):



Element Properties			>
> Input			•
× Results			
Composition %			
Duty Efficiency (%)			
Duty Flow			
Duty NPSH Available			
Duty NPSH Required			
Duty Power			
Duty Pressure Rise			
Element Type			
Flow at NTP			
Elow at STP			
- Heat Transferred			
In Cross Section Flow Area			
In Fluid Phase			
In Mach Number			
In Piezometric Pressure			
In Specific Heat Capacity			
In Stag. Temperature			
In Stagnation Pressure			
In Static Pressure			
In Static Temperature			
In Vapor Pressure			
In Vapor Quality			
In Velocity Pressure			
In Viscosity			
Joule-Thomson Coefficient			
Out Cross Section Flow Area			
Out Density			
Out Fluid Phase			
Out Mach Number			~
		Select All	Clear All
	ОК	Cancel	Help

Figure 55: Element Properties Dialogue Box.

60. Place a checkmark in the box for the following parameters and click **OK**:

Element Properties	
Input	Results
Design Flow Elevation	Duty Flow Duty NPSH Available Duty Pressure Rise In Density In Fluid Phase In Stagnation Pressure In Vapor Pressure In Velocity In Viscosity Out Density Out Fluid Phase Out Stagnation Pressure Out Vapor Pressure Out Vapor Pressure Out Velocity Out Viscosity



	Length	15 m		Length	15 m						
	Nominal Size	6 inch	- · · ·	Nominal Size	4 inch	•					
	Size	154.1 mm		Size	102.3 mm						
	Friction Loss	0.019 bar	_ · · ·	Friction Loss	0.149 bar						•
	Friction Factor	0.017393	_	Friction Factor	0.017842						
	Flow	100.0004 m3/h	· · · ·	Flow	100.0000 m3/h				•		·
	Static Pressure Loss	-0.079 bar		Static Pressure Loss	1.029 bar						
· ·	Stagnation Pressure Lo	ss -0.079 bar	- · · ·	Stagnation Pressure Loss	1.029 bar	•			•	·	
	Out Viscosity	0.890 cP		Out Viscosity	0.890 cP						
	Out Velocity	1.49 m/s		Out Velocity	3.38 m/s						
	Out Density	997.05 kg/m3		Out Density	997.05 kg/m3						
· ·	In Density	997.05 kg/m3		In Density	997.09 kg/m3				•	•	•
	In Velocity	1.49 m/s		In Velocity	3.38 m/s						
1	In Viscosity	0.890 cP		In Viscosity	0.890 cP		2		•		•
Î I	Reynolds No	257094.3		Reynolds No	387302.2		~ I I				
			<u>⊳⊙</u> •	-2		\rightarrow	ं 👳				•
				100 0/			-1 1 L				
Fluid	water .		. Design Flow				Fluid		wate		
Pressure	0 bar g		Elevation	1 m			Pressu		0 ba	ng	
Pressure Elevation	0 bar g 2 m		Elevation In Stagnatio	1 m on Pressure 0.0791 bar g	· · ·		Pressu Elevat	ion	0 ba 10 m	arg n	
Pressure Elevation Viscosity	0 bar g 2 m 0.890 cP		Elevation In Stagnatio In Fluid Phase	1 m n Pressure 0.0791 bar g se Liquid	· · ·		Pressu Elevat Viscos	ion ity	0 ba 10 m 0.89	n 0 cP	
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · ·	Elevation In Stagnatic In Fluid Pha In Velocity	1 m n Pressure 0.0791 bar g se Liquid 1.49 m/s		•	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	(22)
Pressure Elevation Viscosity	0 bar g 2 m 0.890 cP	· · ·	Elevation In Stagnatio In Fluid Pha In Velocity Duty NPSH A	1 m on Pressure 0.0791 bar g se Liquid 1.49 m/s available 10.8 m Fluid			Pressu Elevat Viscos	ion ity erature	0 ba 10 m 0.89 25.0	n 0 cP	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH A Duty Pressu	1 m on Pressure 0.0791 bar g se Liquid 1.49 m/s available 10.8 m Fluid re Rise 0.950 bar		•	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH A Duty Pressu Duty Flow	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s wailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3			Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH 4 Duty Pressu Duty Flow Out Vapor P	1 m on Pressure 0.0791 bar g se Liquid 1.49 m/s vailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure			Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH A Duty Pressu Duty Flow	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s vailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure -0.9816 bar g y 0.890 cP 0			Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH 4 Duty Pressu Duty Flow Out Vapor P Out Viscosit	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ivailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure -0.9816 bar g y 0.890 cP 997.09 kg/m2		· · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · · · · · · · · · · · · · · · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH A Duty Pressu Duty Flow Out Viscosit Out Viscosit Out Density	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ivailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure -0.9816 bar g y 0.890 cP 997.09 kg/m2	· · ·	· · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · · · · · · · · · · · · · · · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH J Duty Pressu Duty Flow Out Viscosit Out Viscosit Out Density In Density	1 m nn Pressure 0.0791 bar g se Liquid 1.49 m/s vailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure -0.9816 bar g y 0.890 cP 997.09 kg/m3 3.38 m/s	· · ·	· · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	· · · · · · · · · · · · · · · · · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH J Duty Pressu Duty Flow Out Viscosit Out Viscosit Out Density In Density	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ivailable 10.8 m Fluid re Rise 0.950 bar 100.0043 m3 ressure -0.9816 bar g y 0.890 cP 997.09 kg/m3 3.38 m/s 997.05 kg/m3 ion Pressure 1.0290 bar g	· · ·	· · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	 · · · · · · · · · · · <li -="" td="" ·<=""><td>Elevation In Stagnatic In Fluid Pha- In Velocity Duty NPSH & Duty Pressu Duty Flow Out Vapor P Out Viscosit Out Density Out Velocity In Density Out Stagnat</td><td>1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ion Pressure 0.950 bar ion Pressure 0.950 bar ion 0.0043 m3 ms ressure -0.9816 bar g y 0.890 cP 997.09 kg/m3 3.38 m/s 997.05 kg/m3 ion Pressure 1.0290 bar g ase</td><td>. .</td><td>· · · ·</td><td>Pressu Elevat Viscos Tempe</td><td>ion ity erature</td><td>0 ba 10 m 0.89 25.0</td><td>n 00 cP 0 C</td><td>(m3</td>	Elevation In Stagnatic In Fluid Pha- In Velocity Duty NPSH & Duty Pressu Duty Flow Out Vapor P Out Viscosit Out Density Out Velocity In Density Out Stagnat	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ion Pressure 0.950 bar ion Pressure 0.950 bar ion 0.0043 m3 ms ressure -0.9816 bar g y 0.890 cP 997.09 kg/m3 3.38 m/s 997.05 kg/m3 ion Pressure 1.0290 bar g ase	. .	· · · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	(m3
Pressure Elevation Viscosity Temperature	0 bar g 2 m 0.890 cP 25.0 C	 · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · · ·	Elevation In Stagnatic In Fluid Pha In Velocity Duty NPSH & Duty Pressu Duty Flow Out Vapor P Out Viscosit Out Density Out Velocity In Density Out Stagnat Out Fluid Ph	1 m in Pressure 0.0791 bar g se Liquid 1.49 m/s ion Pressure 0.950 bar ion Pressure 0.950 bar ion 0.0043 m3 ms ressure -0.9816 bar g y 0.890 cP 997.09 kg/m3 3.38 m/s 997.05 kg/m3 ion Pressure 1.0290 bar g ase	. .	· · · ·	Pressu Elevat Viscos Tempe	ion ity erature	0 ba 10 m 0.89 25.0	n 00 cP 0 C	/m3

61. The hydraulic model should now look like the screenshot given below (Figure 56).

Figure 56: Hydraulic Model with Pump Properties.

62. Save your flowsheet.

Task 5 – Compare the FluidFlow Results to Hand Calculation

FluidFlow software is designed to allow the modeling of fluid behaviour within complex piping systems, and accurately predict how the system will work for a given set of design conditions.

In this task, we will verify the accuracy of FluidFlow against our hand calculation.

Given:

 $P_1 = 0 barg$



 $P_{2} = 0 \text{ barg}$ $z_{1} = 2 m$ $z_{2} = 10 m$ Suction line size = 6" SCH 40 Discharge line size = 4" SCH 40 $L_{-1} = 15.0 m$ $L_{-2} = 15.0 m$ Volumetric Flow Rate, $\dot{q} = 100 \frac{m^{3}}{h}$ Water at 25°C

Required:

$$\begin{split} & Velocity, V_{-1} = V_{1} = ? \\ & Velocity, V_{-2} = V_{2} = ? \\ & Reynolds Number, Re_{-1} = ? \\ & Reynolds Number, Re_{-2} = ? \\ & Darcy Friction Factor, f_{D_{-1}} = ? \\ & Darcy Friction Factor, f_{D_{-2}} = ? \\ & Pump Differential Head, W'or \Delta h = ? \\ & Pump Differential Pressure, \Delta P_{Differential} = ? \\ & Friction loss_{-1} = -\Delta P_{-1} = ? \\ & Friction loss_{-2} = -\Delta P_{-2} = ? \\ & NPSH_{Available} = ? \\ \end{split}$$

Solution:

6" SCH 40, I. D. = D_{-1} = 154. 1 mm = 0.1541 m 4" SCH 40, I. D. = D_{-2} = 102. 3 mm = 0.1023 m Density of Water at 25. 0°C from FluidFlow Calculated Properties Database



$$\rho_{H_2 0} = 997.05 \frac{kg}{m^3}$$

Viscosity of Water at 25.0°C from FluidFlow Calculated Properties Database

$$\mu_{H_2^0} = 0.890 \, cP$$

Mechanical Energy Balance Equation:

$$W' = \Delta z \frac{g}{g_c} + \frac{\Delta V^2}{2g_c} + \frac{\Delta P}{\rho} + \sum F$$

Summation of Frictional Losses:

$$\sum F = F_{Line} + F_{Fittings} + F_{Contraction} + F_{Expansion} + F_{Metering}$$

$$\begin{split} \frac{\Delta P}{\rho} &= 0 \left(Constant \, pressure, P_1 = P_2 \right) \\ F_{Fittings} &= F_{Contraction} = F_{Expansion} = F_{Metering} = 0 \\ F_{Line_{-1}} &= h_{Line_{-1}} = \frac{4f_{F_{-1}}L_{-1}V_{-1}^2}{2D_{-1}g_c} \\ F_{Line_{-2}} &= h_{Line_{-2}} = \frac{4f_{F_{-2}}L_{-2}V_{-2}^2}{2D_{-2}g_c} \\ \sum F &= F_{Line_{-1}} + F_{Line_{-2}} = \frac{4f_{F_{-1}}L_{-1}V_{-1}^2}{2D_{-1}g_c} + \frac{4f_{F_{-2}}L_{-2}V_{-2}^2}{2D_{-2}g_c} = \frac{2f_{F_{-1}}L_{-1}V_{-1}^2}{D_{-1}g_c} + \frac{2f_{F_{-2}}L_{-2}V_{-2}^2}{D_{-2}g_c} \end{split}$$

Applying the above conditions to Mechanical Energy Balance equation:

$$W' = \Delta z \frac{g}{g_c} + \frac{\Delta V^2}{2g_c} + 0 + F_{Line_{-1}} + F_{Line_{-2}}$$
$$W' = (z_2 - z_1) \frac{g}{g_c} + \frac{V_2^2 - V_1^2}{2g_c} + \frac{2f_{F_{-1}} L_{-1} V_{-1}^2}{D_{-1} g_c} + \frac{2f_{F_{-2}} L_{-2} V_{-2}^2}{D_{-2} g_c}$$

Let us first solve for the cross - sectional area of the pipes " - 1"and " - 2".

Velocity, $V_{-1} = V_1 = \frac{q}{S_{-1}} = \frac{q}{\frac{\pi}{4}(D_{-1})^2} = \frac{100\frac{m^3}{h} \times \frac{1h}{3600 s}}{\frac{\pi}{4}(0.1541 m)^2} = 1.4894\frac{m}{s}$

Velocity,
$$V_{-2} = V_2 = \frac{q}{S_{-2}} = \frac{q}{\frac{\pi}{4}(D_{-2})^2} = \frac{100\frac{m^3}{h} \times \frac{1h}{3600s}}{\frac{\pi}{4}(0.1023 m)^2} = 3.3795\frac{m}{s}$$



Let us now solve for the value of the Reynolds number.

$$Re_{-1} = \frac{D_{-1}V_{-1}\rho}{\mu} = \frac{(0.1541 m)(1.4894 \frac{m}{s})(997.05 \frac{kg}{m^3})}{0.890 cP \times \frac{Pa-s}{1000 cP}} = 257122.9957$$
$$Re_{-2} = \frac{D_{-2}V_{-2}\rho}{\mu} = \frac{(0.1023 m)(3.3795 \frac{m}{s})(97.05 \frac{kg}{m^3})}{0.890 cP \times \frac{Pa-s}{1000 cP}} = 387306.7052$$

Let us solve the Fanning Friction Factors, $f_{F_{-1}}$ and $f_{F_{-2}}$

Perry's Chemical Engineer's Handbook - 8th ed. The Colebrook formula Equation (6 - 38)

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{\epsilon}{3.7D} + \frac{1.256}{Re\sqrt{f_F}} \right] Re > 4,000$$
$$\frac{1}{\sqrt{f_{F_{-1}}}} = -4 \log \log \left[\frac{\epsilon}{3.7D_{-1}} + \frac{1.256}{Re_{-1}\sqrt{f_{F_{-1}}}} \right]$$
$$\frac{1}{\sqrt{f_{F_{-2}}}} = -4 \log \log \left[\frac{\epsilon}{3.7D_{-2}} + \frac{1.256}{Re_{-2}\sqrt{f_{F_{-2}}}} \right]$$

Perry's Chemical Engineer's Handbook – 8th ed. Table 6 – 1 Value of Surface Roughness for Various Materials Commercial steel or wrought iron, $\epsilon = 0.0457$ mm Substitute the values of D, ϵ , and Re.

$$\frac{1}{\sqrt{f_{F_{-1}}}} = -4\log\log\left[\frac{0.0457 \, mm}{3.7(154.1 \, mm)} + \frac{1.256}{257122.9957\sqrt{f_{F_{-1}}}}\right]$$

$$f_{F_{-1}} = 4.3038 \times 10^{-3}$$

$$\frac{1}{\sqrt{f_{F_{-2}}}} = -4\log\log\left[\frac{0.0457 \, mm}{3.7(102.3 \, mm)} + \frac{1.256}{387306.7052\sqrt{f_{F_{-2}}}}\right]$$

$$f_{F_{-2}} = 4.3963 \times 10^{-3}$$

Let us calculate for the value of Darcy friction factors



$$f_{D_{-1}} = 4f_{F_{-1}} = 4(4.3038 \times 10^{-3})$$

$$f_{D_{-1}} = 0.0172$$

$$f_{D_{-2}} = 4f_{F_{-2}} = 4(4.3963 \times 10^{-3})$$

$$f_{D_{-2}} = 0.0176$$

$$\begin{split} \Delta z \frac{g}{g_c} &= \left(z_2 - z_1\right) \frac{g}{g_c} = (10 - 2)m \times \frac{9.80665\frac{m}{s^2}}{1\frac{kg-m}{N-s^2}} = 78.4532\frac{N-m}{kg} \\ \frac{\Delta V^2}{2g_c} &= \frac{V_2^2 - V_1^2}{2g_c} = \frac{\left(3.3795\frac{m}{s}\right)^2 - \left(1.4894\frac{m}{s}\right)^2}{2\left(1\frac{kg-m}{N-s^2}\right)} = 4.6014\frac{N-m}{kg} \\ F_{Line_{-1}} &= \frac{2f_{F_{-1}}L_{-1}V_{-1}^2}{D_{-1}g_c} = \frac{2(4.3038 \times 10^{-3})(15\,m)\left(1.4894\frac{m}{s}\right)^2}{(0.1541\,m)\left(1\frac{kg-m}{N-s^2}\right)} = 1.8586\frac{N-m}{kg} \\ F_{Line_{-2}} &= \frac{2f_{F_{-2}}L_{-2}V_{-2}^2}{D_{-2}g_c} = \frac{2(4.3963 \times 10^{-3})(15\,m)\left(3.3795\frac{m}{s}\right)^2}{(0.1023\,m)\left(1\frac{kg-m}{N-s^2}\right)} = 14.7244\frac{N-m}{kg} \end{split}$$

$$W' = \Delta z \frac{g}{g_c} + \frac{\Delta V^2}{2g_c} + 0 + F_{Line_{-1}} + F_{Line_{-2}}$$
$$W' = (78.4532 + 4.6014 + 1.8586 + 14.7244) \frac{N-m}{kg}$$
$$W' = 99.6376 \frac{N-m}{kg} \times \frac{1 kg}{9.80665 N}$$
$$W' = \Delta h = 10.1602 m (Pump Differential Head)$$

$$\Delta P_{Differential} = \rho \frac{g}{g_c} \Delta h = \left(997.05 \frac{kg}{m^3}\right) \left(9.80665 \frac{N}{kg}\right) (10.1602 m)$$

$$\Delta P_{Differential} = 99343.59463 Pa \times \frac{1.01325 bar}{101325 Pa}$$

$$\Delta P_{Differential} = 0.9934 bar (Pump Differential Pressure)$$

Let us calculate for the value of frictional losses



Friction loss_{-1} =
$$-\Delta P_{-1} = \frac{2f_{F_{-1}}L_{-1}V_{-1}^2\rho}{D_{-1}g_c}$$

 $Friction \, loss_{-1} = -\Delta P_{-1} = \frac{2(4.3038 \times 10^{-3})(15\,m)(1.4894\frac{m}{s})^2(997.05)}{(0.1541\,m)(1\frac{kg-m}{N-s^2})} = 1853\,Pa$

Friction
$$loss_{-1} = -\Delta P_{-1} = 1853 Pa \times \frac{1.01325 bar}{101325 Pa}$$

$$Friction \ loss_{-1} = - \ \Delta P_{-1} = \ 0.0185 \ bar$$

Friction loss_{-2} =
$$F_{Line_{-2}} = h_{Line_{-2}} = \frac{-\Delta P_{-2}}{\rho} = \frac{4f_{F_{-2}}L_{-2}V_{-2}^2}{2D_{-2}g_c}$$

 $Friction \ loss_{-2} = - \ \Delta P_{-2} = \frac{2f_{F_{-2}}L_{-2}v_{-1}^{2}\rho}{D_{-2}g_{c}}$

Friction loss₋₂ =
$$-\Delta P_{-2} = \frac{2(4.3963 \times 10^{-3})(15 m)(3.3795 \frac{m}{s})^2(997.05)}{(0.1023 m)(1\frac{kg-m}{N-s^2})} = 14681 Pa$$

Friction $loss_{-2} = -\Delta P_{-2} = 14681 Pa \times \frac{1.01325 bar}{101325 Pa}$

 $Friction \ loss_{-2} = -\Delta P_{-2} = 0.1468 \ bar$

$$\begin{split} NPSH_{Available} &= \frac{g_c}{g} \left[\frac{P_{suction} - P^{sat}}{\rho} \right] = \frac{g_c}{g} \left[\frac{In \, Stagnation \, Pressure - In \, Vapor \, Pressure}{\rho} \right]_{Pump} \\ NPSH_{Available} &= \frac{1 \, kg}{9.80665 \, N} \left[\frac{[0.0791 \, barg - (-0.9816 \, barg)] \times \frac{101325 \, Pa}{1.01325 \, bar}}{997.05 \frac{kg}{m^3}} \right] \\ NPSH_{Available} &= 10.\,8481 \, m = 10,\,8481 \, mm \end{split}$$

Results Comparison:

Description	Unit	FluidFlow Results	Hand Calculation	% Difference
	m/s	1.49	1.49	0%
Velocity, V_{-2}, V_{2}	m/s	3.38	3.38	0%
Reynolds Number, Re_{-1}	-	257094	257123	0.0113%
Reynolds Number, Re ₋₂	-	387302	387307	0.0013%
Darcy Friction Factor, $f_{D_{-1}}$	-	0.0174	0.0172	1.1561%
Darcy Friction Factor, $f_{D_{-2}}$	-	0.0178	0.0176	1.1299%
Pump Diff. Head, W or Δh	m	9.715	10.160	4.4780%
Pump Diff. Pressure, ΔP_{Di}	bar	0.950	0.993	4.4262%



Friction loss1, $-\Delta P_{-1}$	bar	0.019	0.019	0%
Friction loss_2, $-\Delta P_{-2}$	bar	0.149	0.147	1.3514%
NPSH _{Available}	m	10.8	10.8	0%

Commentary:

The results compare very well with the hand calculation.