# FluidFlow

# The Flow of Liquid via a Pump



Flite Software N.I. Ltd, Block E, Balliniska Business Park, Springtown Rd,
Derry, BT48 0LY, N. Ireland. T: 44 (0) 2871 279227 |
E: sales@fluidflowinfo.com | www.fluidflowinfo.com

# The flow of a Liquid via Pump

## Problem

Water at 25ºC 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).

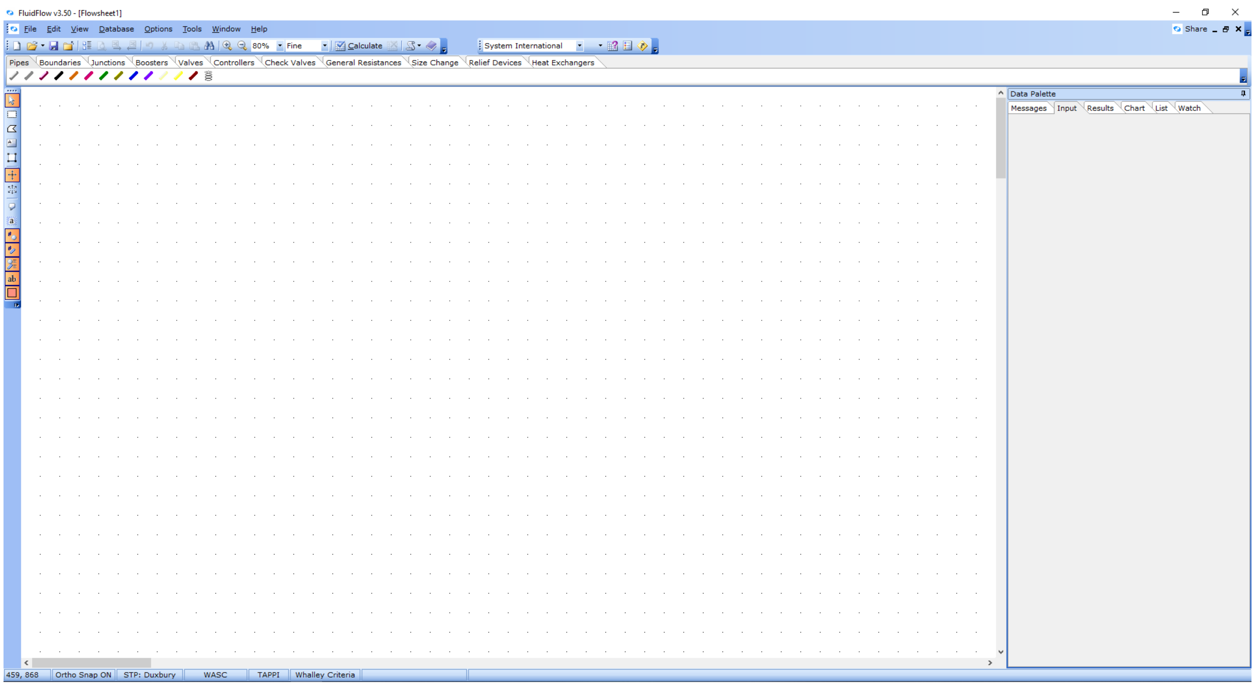


**Figure 1: New flowsheet user interface.**

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).

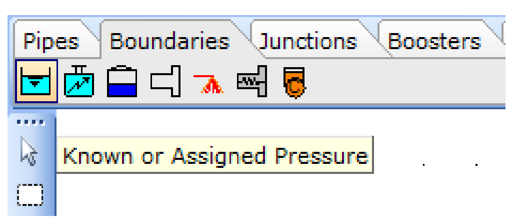



**Figure 2: Known or Assigned Pressure Node.**

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).

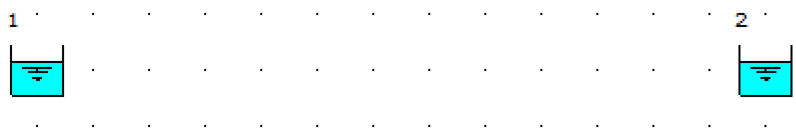



**Figure 3: Known Pressure Nodes.**

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).

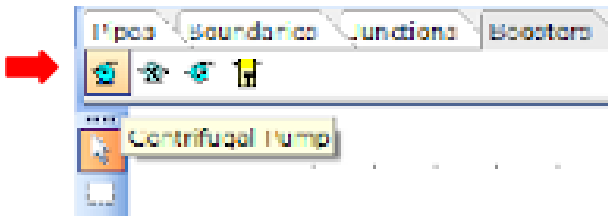


**Figure 4: Centrifugal Pump Icon.**

*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).

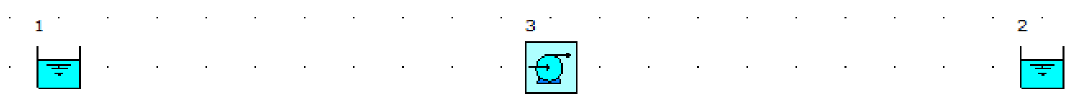



**Figure 5: Centrifugal Pump in the middle of the Known Pressure Nodes.**

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).

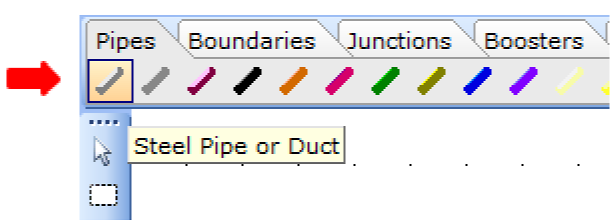



**Figure 6: Steel Pipe of Duct Icon.**

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 (✅). This indicates that the software is ready to connect our new node. The hydraulic model will appear as shown below (Figure 7):

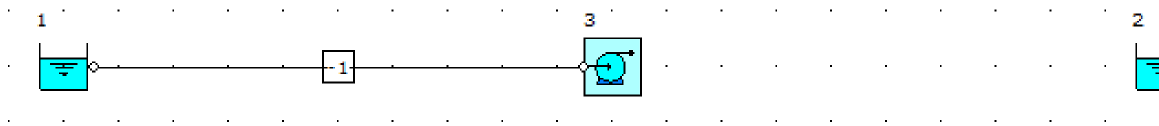



**Figure 7: Hydraulic Model.**

**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).

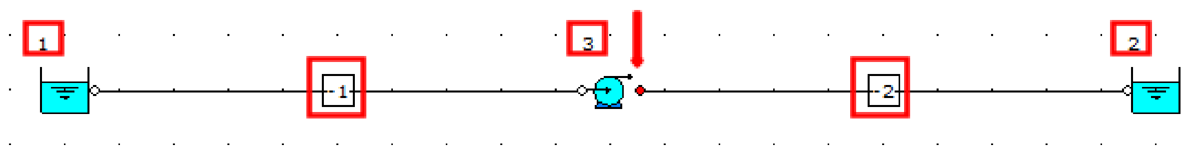



**Figure 8: Hydraulic Model.**

**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):

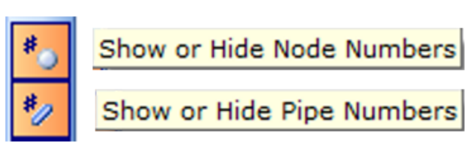



**Figure 9: Show or Hide Node/Pipe Numbers buttons.**

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).

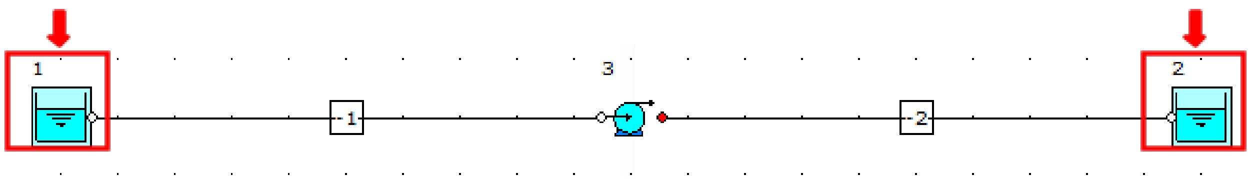



**Figure 10: Highlighted Boundary Nodes.**

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

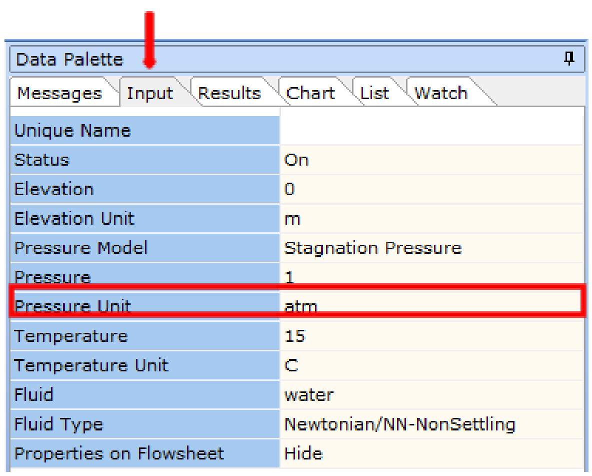



**Figure 11: Input Inspector.**

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.

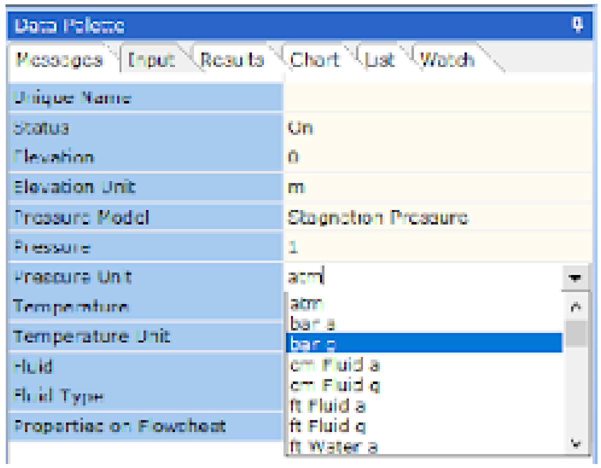



**Figure 12: Pressure Units.**

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).

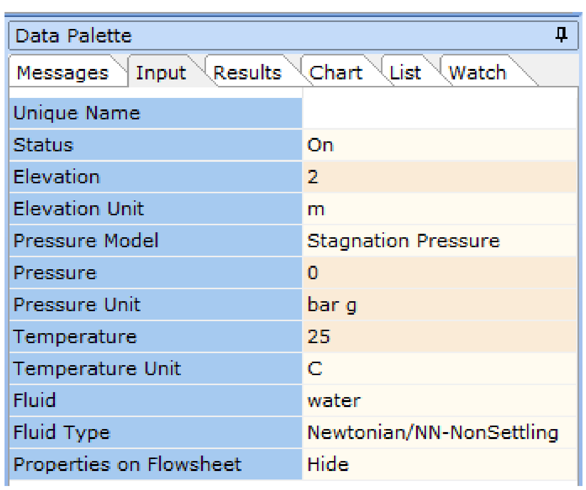



**Figure 13: Input Inspector at Node 1.**

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).

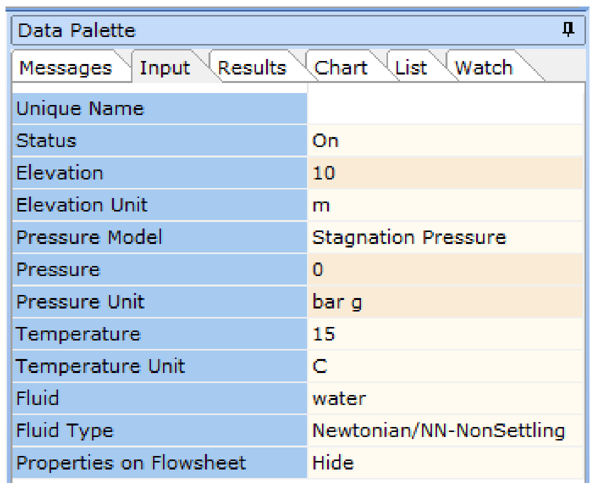



**Figure 14: Input Inspector at Node 2.**

For the temperature input, we don't need to change it to 25ºC. 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).

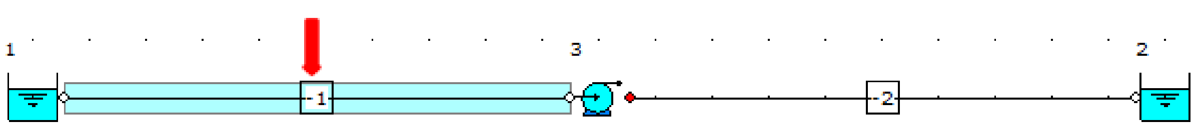



**Figure 15: Highlighted Pipe "-1".**

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

| In this cell… | Enter… |
|---|---|
| Length | 15 |

| | |
|---|---|
| Nominal Size | 6 inch |

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):

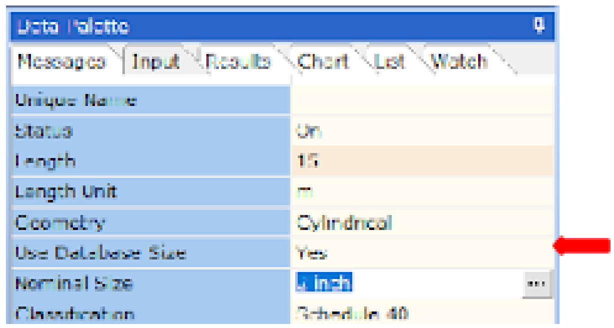



**Figure 16: Nominal Size with 3 dots button.**

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

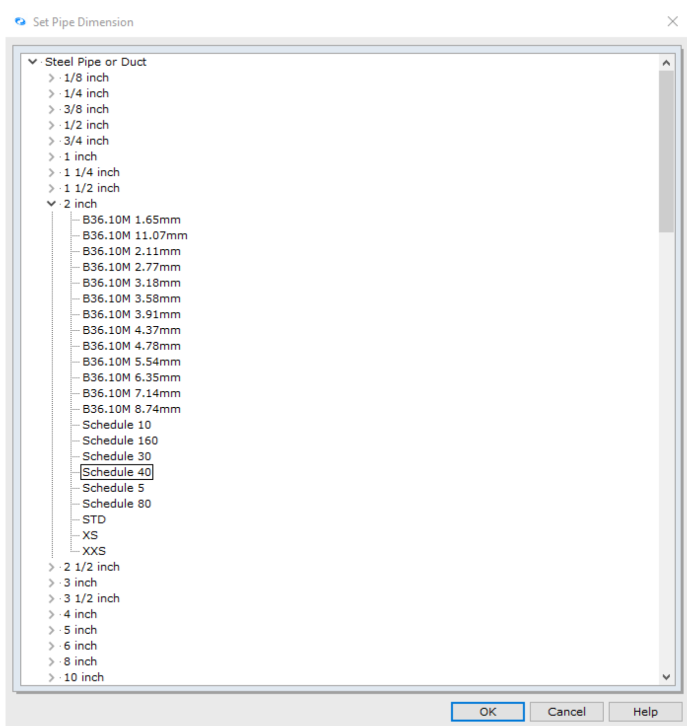



**Figure 17: Set Pipe Dimension Dialog Box.**

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).

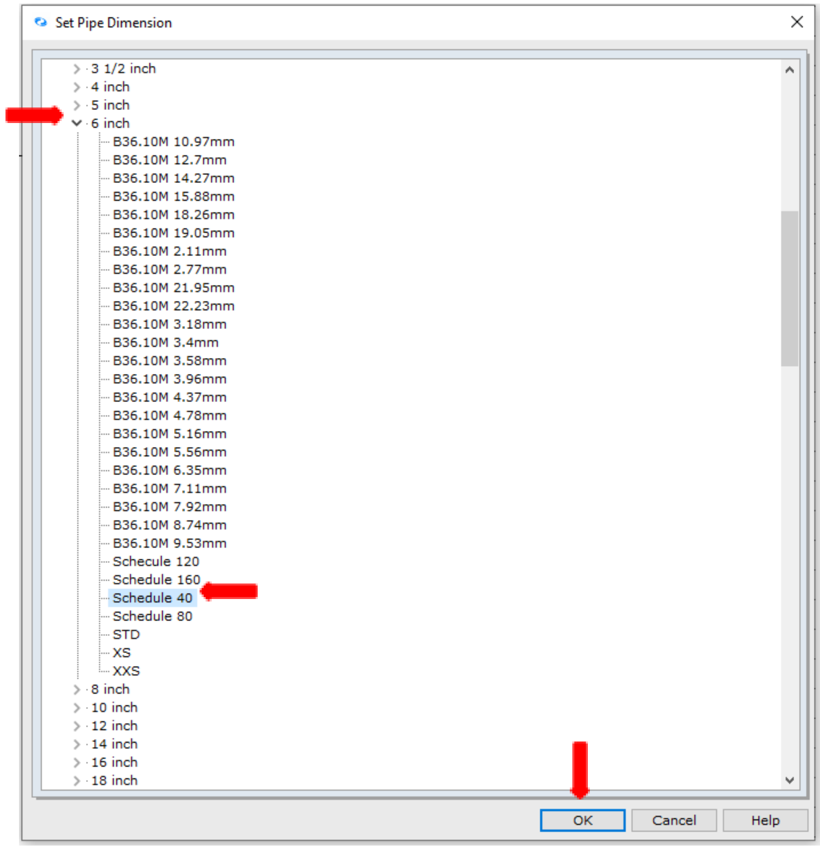



**Figure 18: Set Pipe Dimension Dialog Box.**

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

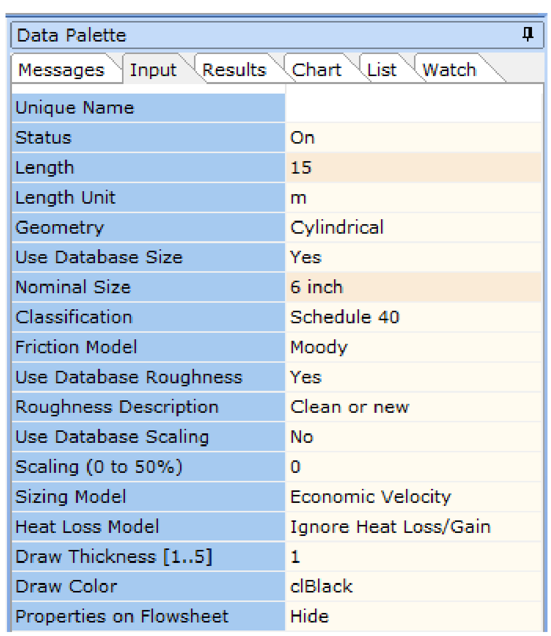


Figure 19: Input Inspector at Pipe Number "-1".

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).

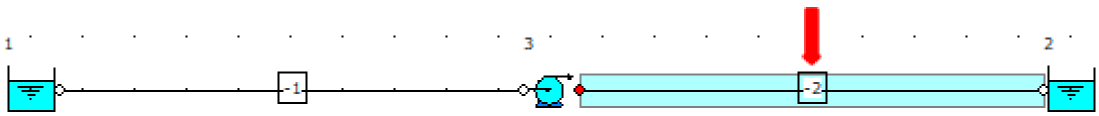



**Figure 20: Highlighted Pipe "-2".**

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):

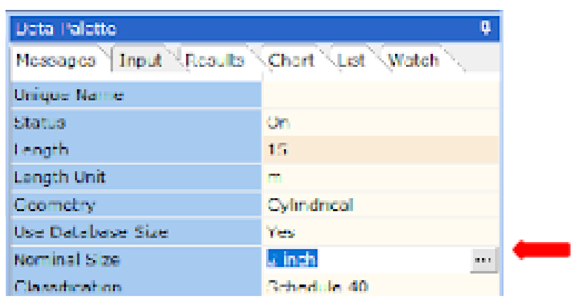



**Figure 21: Nominal Size with 3 dots button.**

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

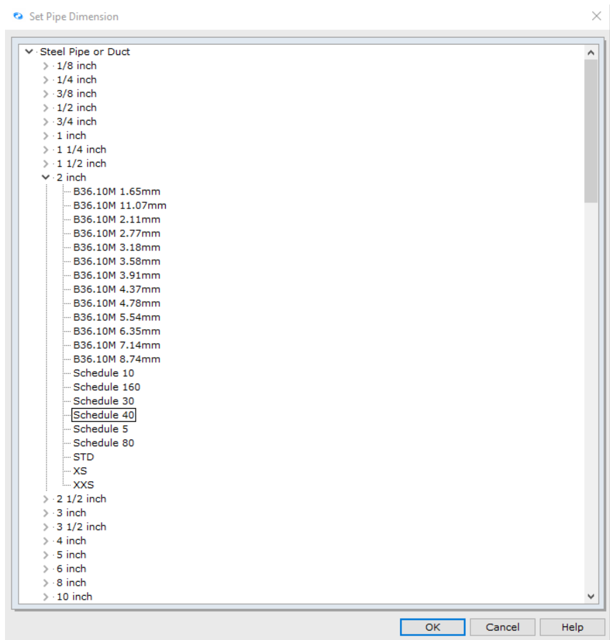



**Figure 22: Set Pipe Dimension Dialog Box.**

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).

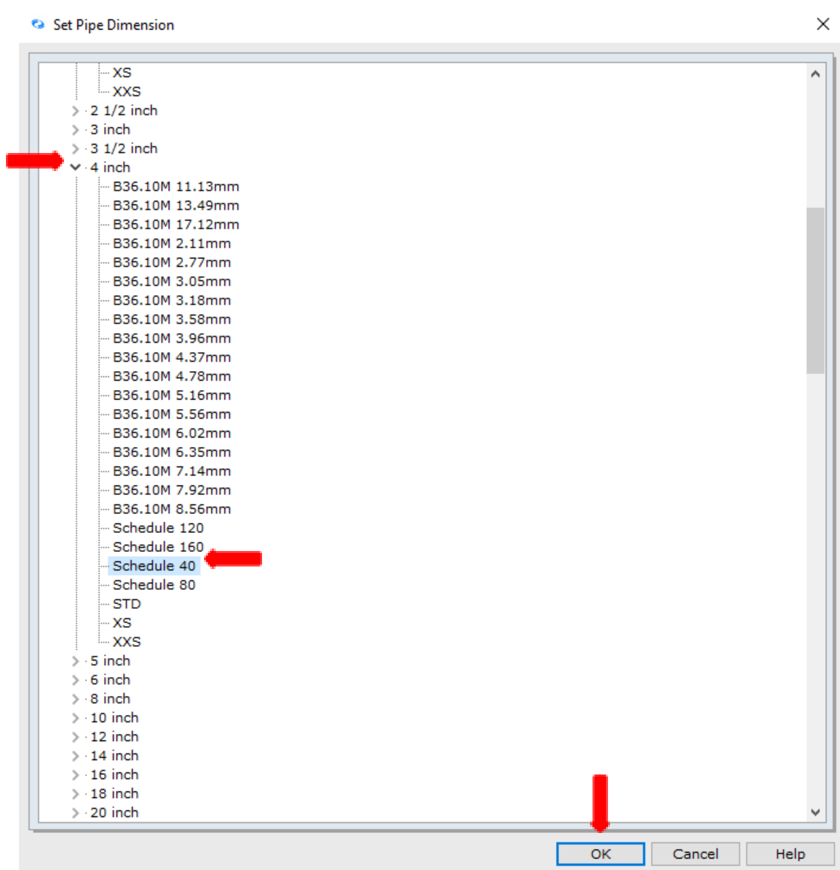
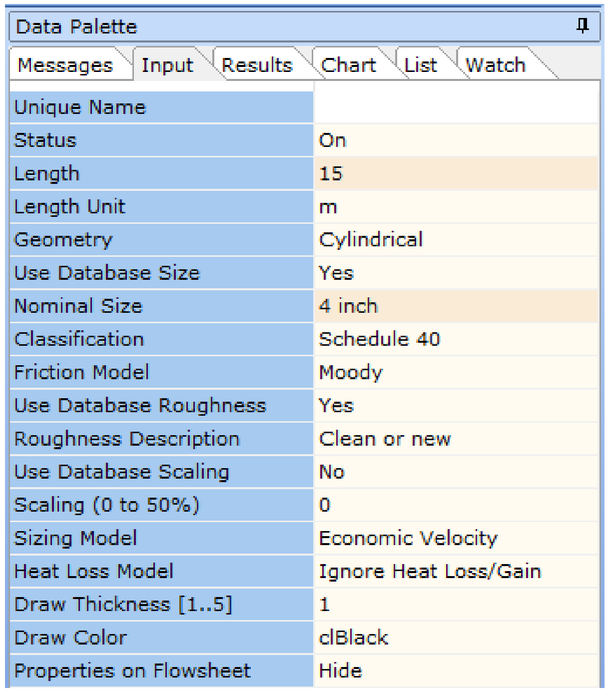


**Figure 23: Set Pipe Dimension Dialog Box.**

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 [1..5] | 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).

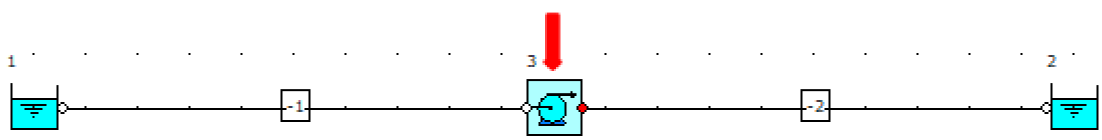



**Figure 25: Highlighted Centrifugal Pump Node.**

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).

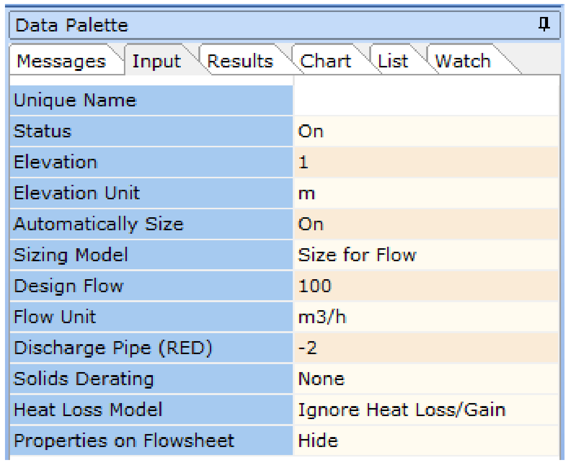



**Figure 26: Input Inspector at Centrifugal Pump.**

**Note:** The *Size for Flow* sizing model is used to maintain a flow rate of 100 $m^3$/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):

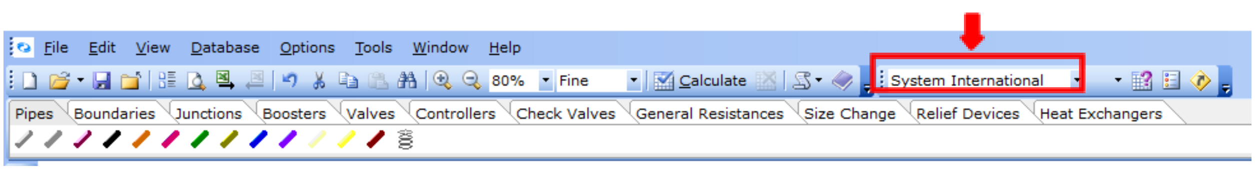



**Figure 27: Unit Selector.**

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).

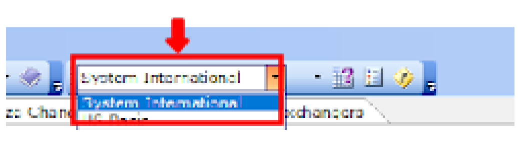


**Figure 28: Unit Selector Drop-Down Menu.**

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).

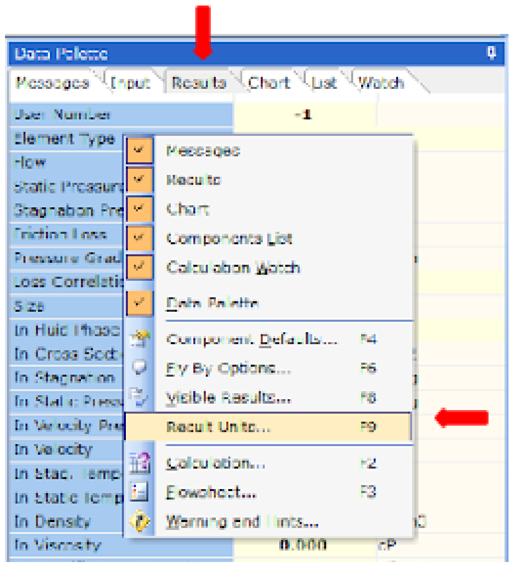



**Figure 29: Result Units.**

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

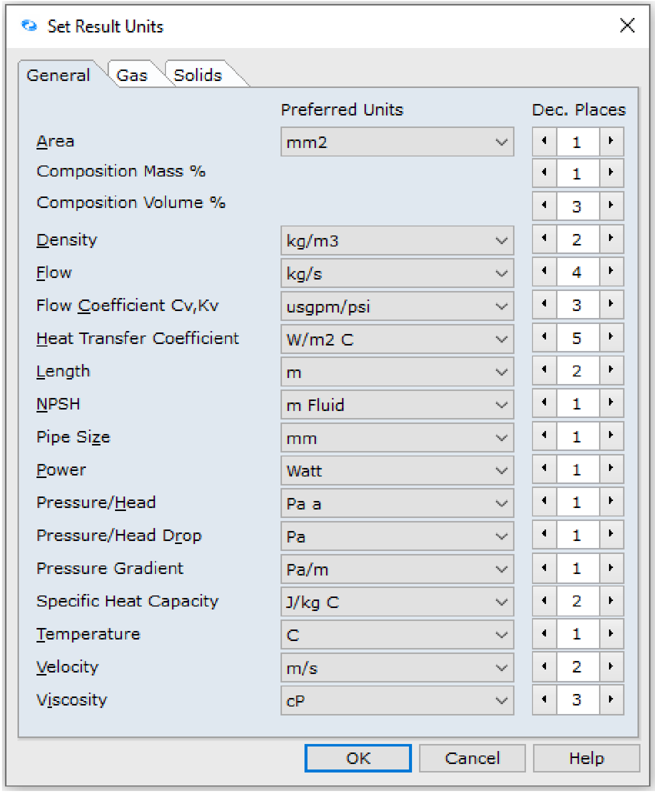



**Figure 30: Set Result Units Dialogue Box.**

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

| In this unit… | Select… |
|---|---|
| Flow | $m^3/h$ |
| 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.

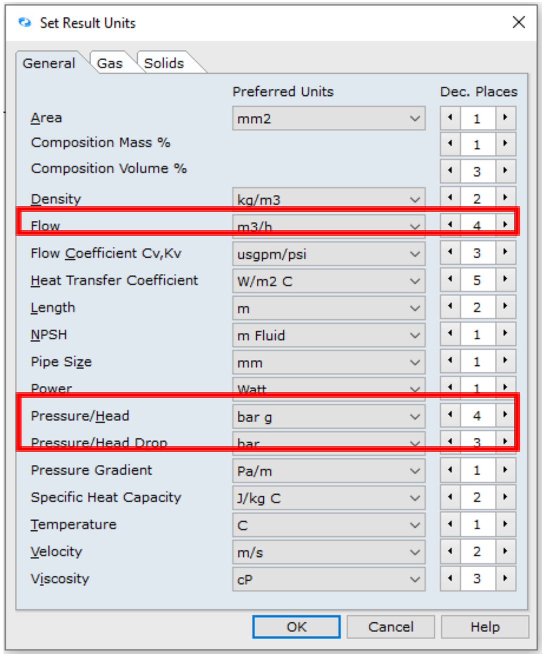



**Figure 31: Modified Set Result Units Dialogue Box.**

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).

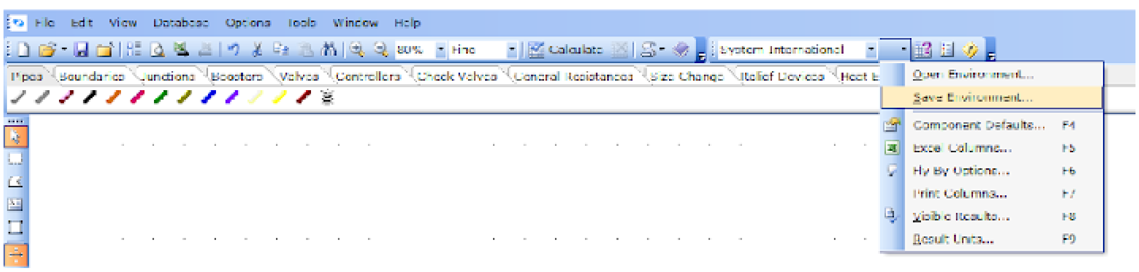


**Figure 32: Save Environment Option.**

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

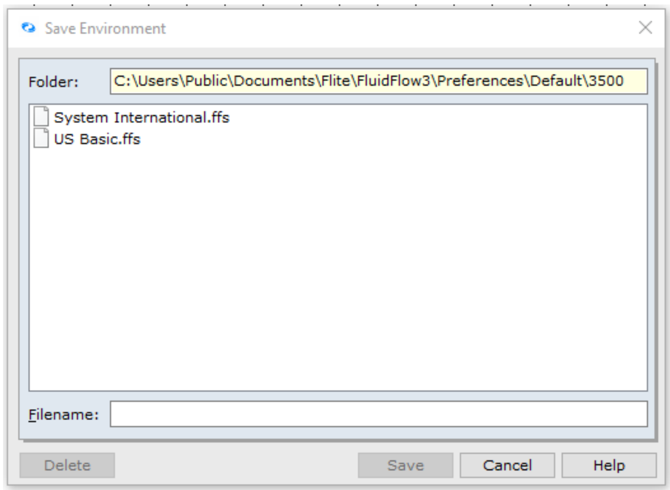



**Figure 33: Save Environment Dialogue Box.**

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

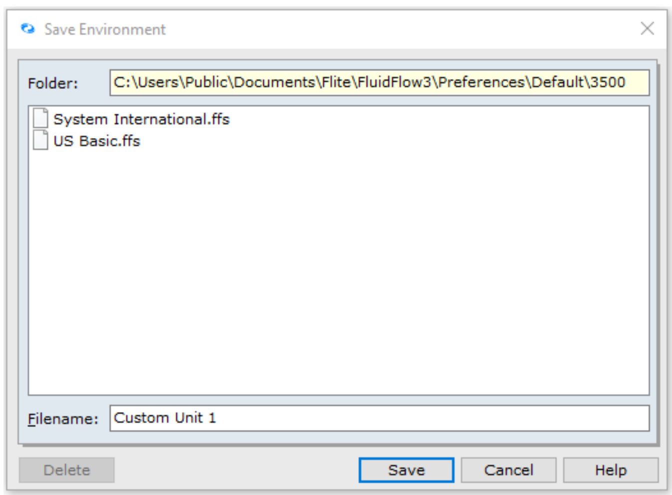



**Figure 34: Modified Save Environment Dialogue Box.**

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

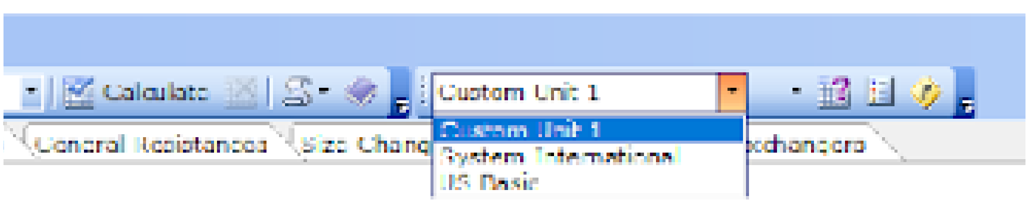



**Figure 35: Unit Set Drop-Down Menu.**

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):

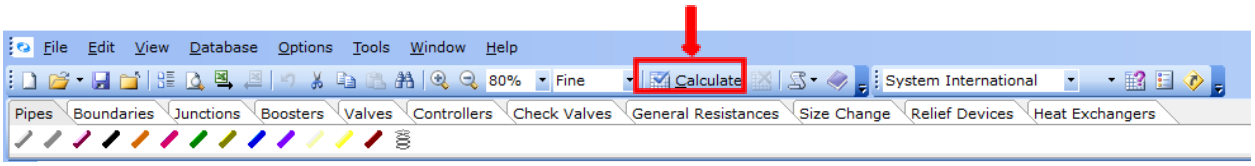



**Figure 36: Calculate Button.**

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).

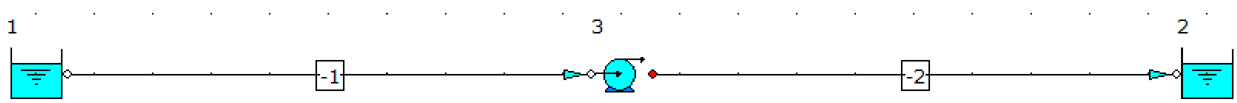



**Figure 37: Converged Hydraulic Model**

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

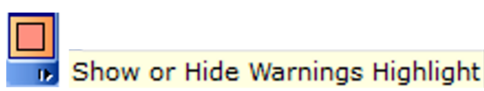



**Figure 38: Show or Hide Warnings Highlight Button.**

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.

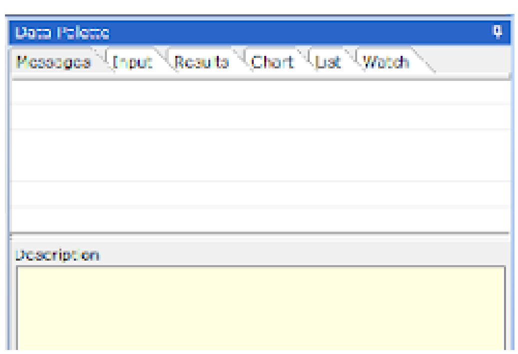
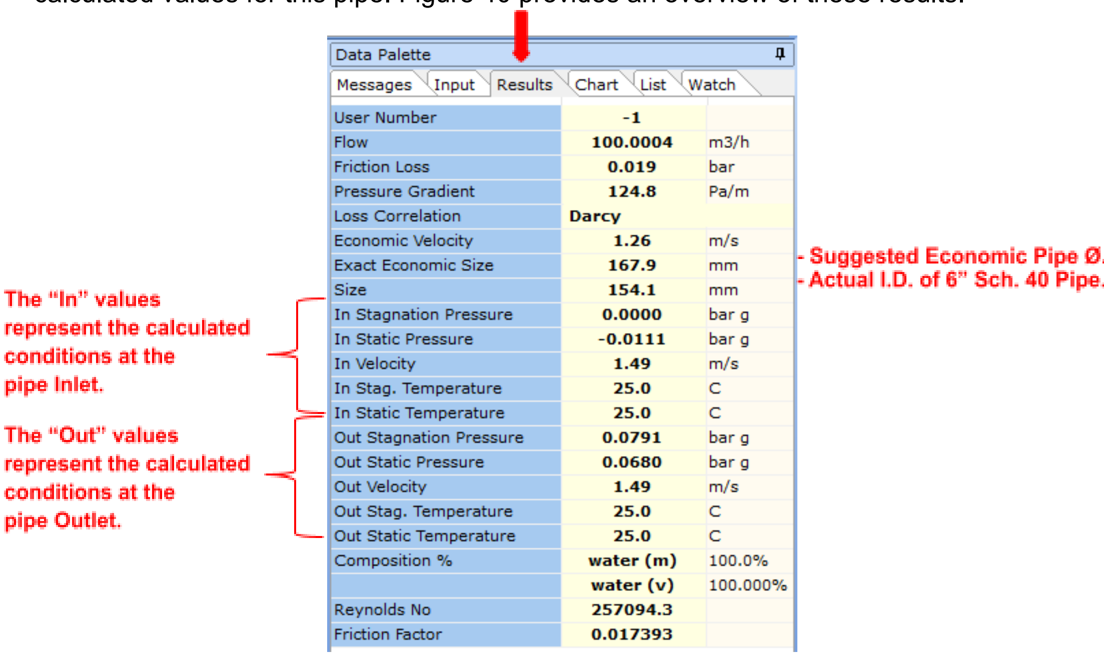



**Figure 39: Warning Messages Tab.**

**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.

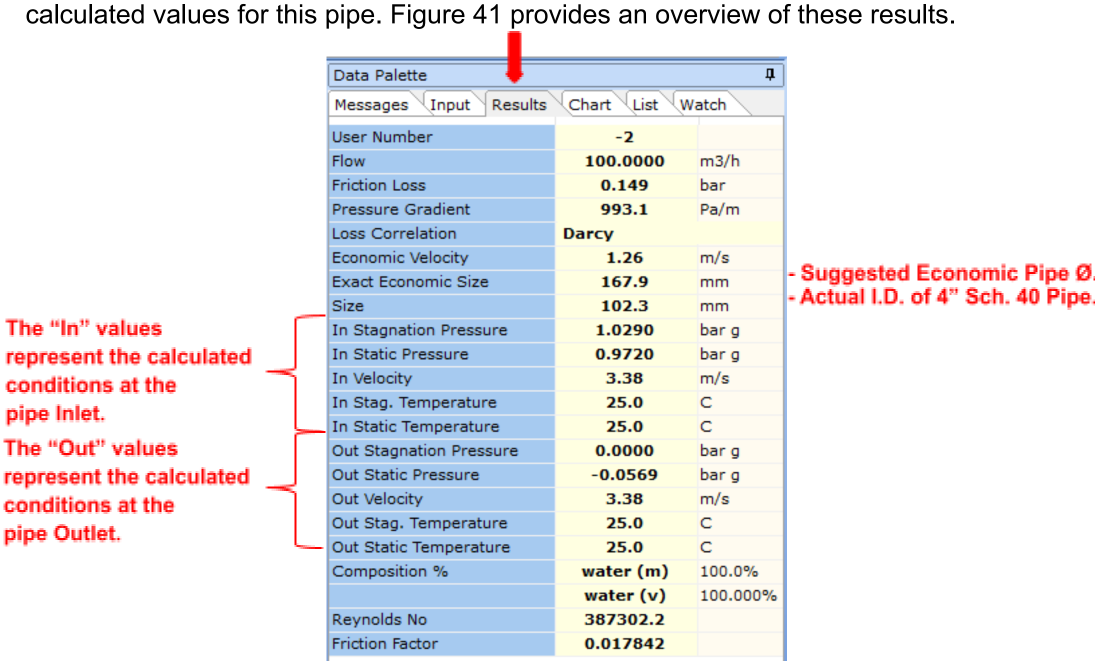
41. Left-click the pipe number -1 and select the *Results* tab on the *Data Palette*. We can see all the calculated values for this pipe. Figure 40 provides an overview of these results.




| | | |
|---|---|---|
| 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 |
| Exact Economic Size | 167.9 | mm |
| Size | 154.1 | mm |
| In Stagnation Pressure | 0.0000 | bar g |
| In Static Pressure | -0.0111 | bar g |
| In Velocity | 1.49 | m/s |
| In Stag. Temperature | 25.0 | C |
| In Static Temperature | 25.0 | C |
| Out Stagnation Pressure | 0.0791 | bar g |
| Out Static Pressure | 0.0680 | bar g |
| Out Velocity | 1.49 | m/s |
| Out Stag. Temperature | 25.0 | C |
| Out Static Temperature | 25.0 | C |
| 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.




| | | |
|---|---|---|
| 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 |
| Exact Economic Size | 167.9 | mm |
| Size | 102.3 | mm |
| In Stagnation Pressure | 1.0290 | bar g |
| In Static Pressure | 0.9720 | bar g |
| In Velocity | 3.38 | m/s |
| In Stag. Temperature | 25.0 | C |
| In Static Temperature | 25.0 | C |
| Out Stagnation Pressure | 0.0000 | bar g |
| Out Static Pressure | -0.0569 | bar g |
| Out Velocity | 3.38 | m/s |
| Out Stag. Temperature | 25.0 | C |
| Out Static Temperature | 25.0 | C |
| 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).

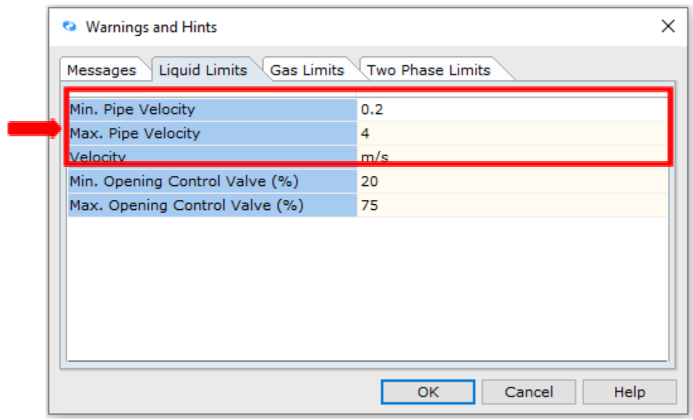



**Figure 42: Warning and Hints: Liquid Limits.**

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.

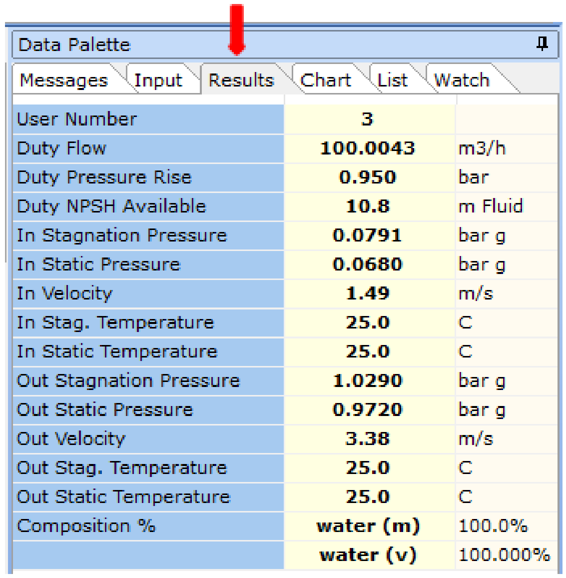



**Figure 43: Calculated Results for Pump.**

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).

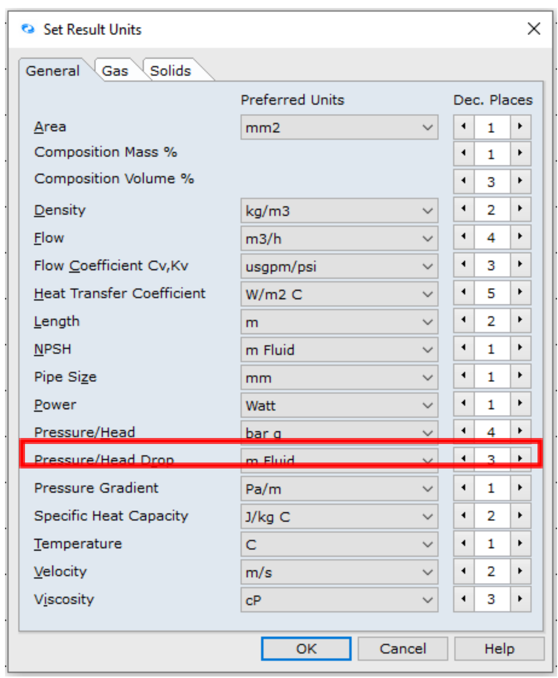
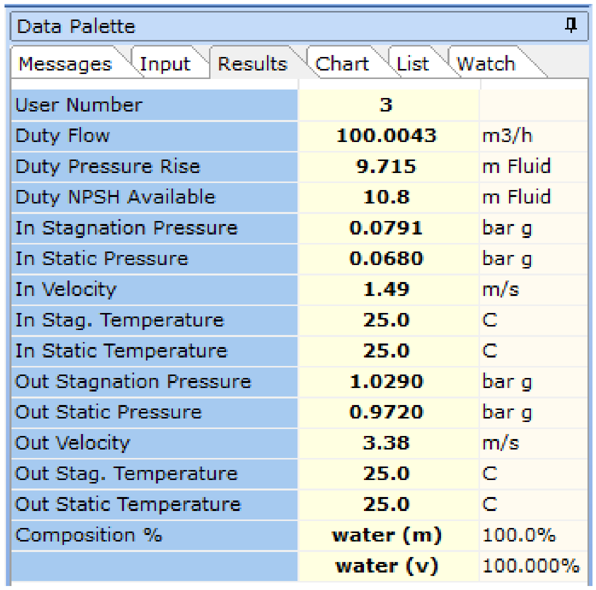



**Figure 44: Modified Set Result Units Dialogue Box.**

In this case, the duty pressure rise is **9.7 m Fluid** (Figure 45). We know this to be true since ΔH = ΔP/ρ*g (ΔH = 95000/(997.09*9.80665) = 9.7 m Fluid).



Data Palette

Messages | Input | Results | Chart | List | 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 | C |
| In Static Temperature | 25.0 | C |
| 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 | C |
| Out Static Temperature | 25.0 | C |
| 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 **clRed** (Figure 46).

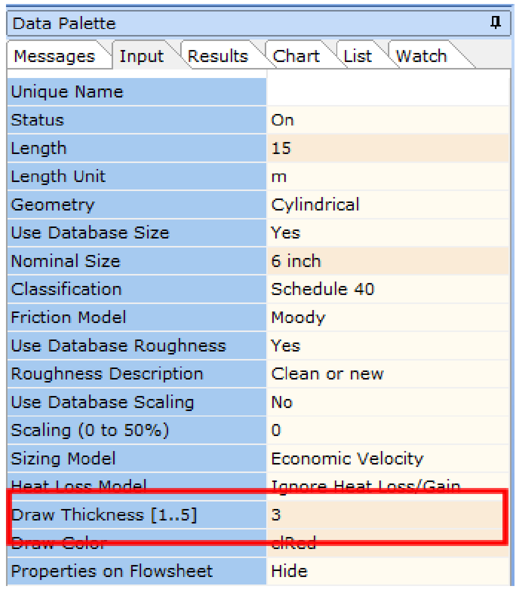



**Figure 46: Modified Draw Thickness and Draw Color.**

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

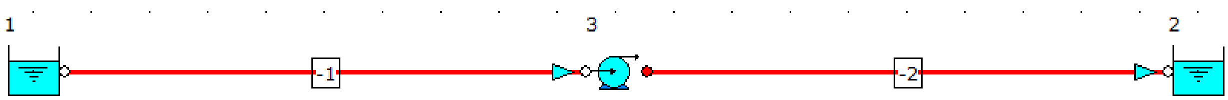



**Figure 47: Hydraulic Model with Modified Draw Thickness and Draw Color.**

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).

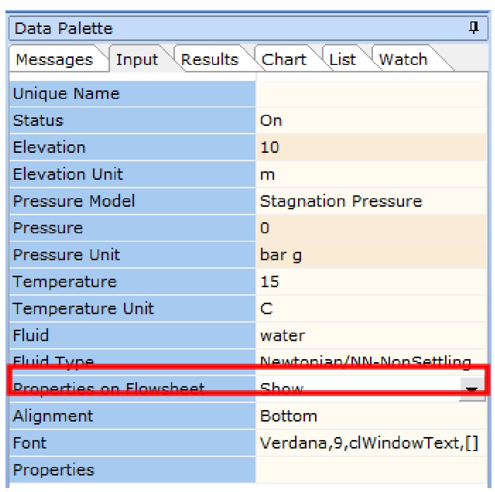



**Figure 48: Show Properties on Flowsheet.**

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

FluidFlow

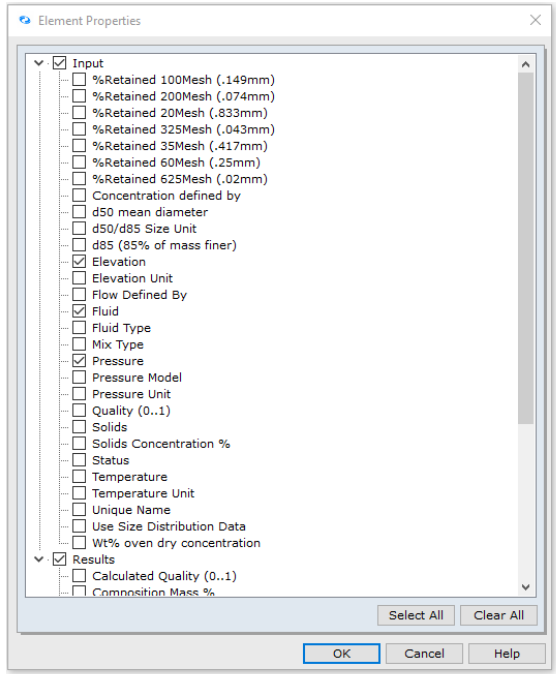



**Figure 49: Element Properties Dialogue Box.**

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

| Element Properties | |
|---|---|
| Input | Results |
| Elevation<br>Fluid<br>Pressure | Density<br>Temperature<br>Viscosity |

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

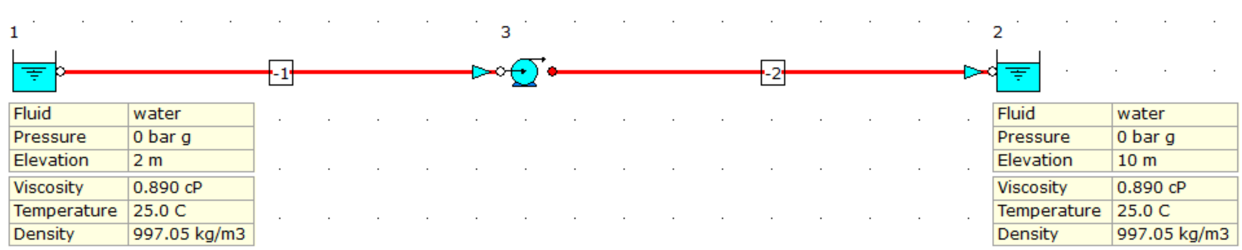



**Figure 50: Hydraulic Model with Inlet and Outlet Boundary Properties.**

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).

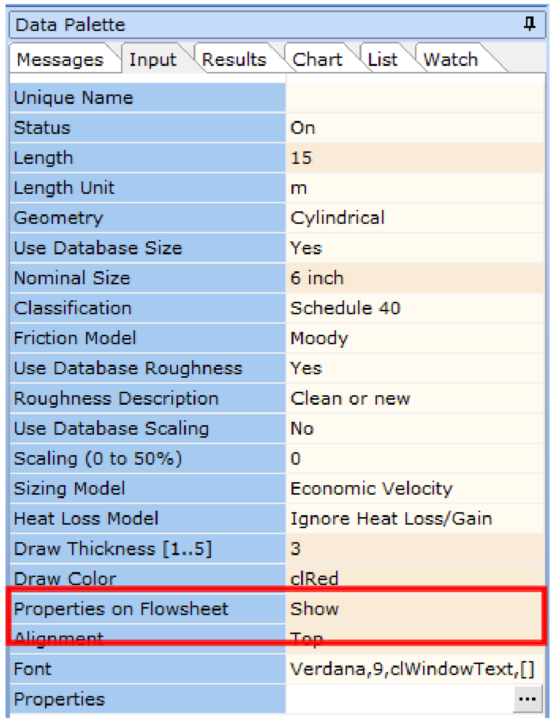



**Figure 51: Show Properties on Flowsheet.**

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

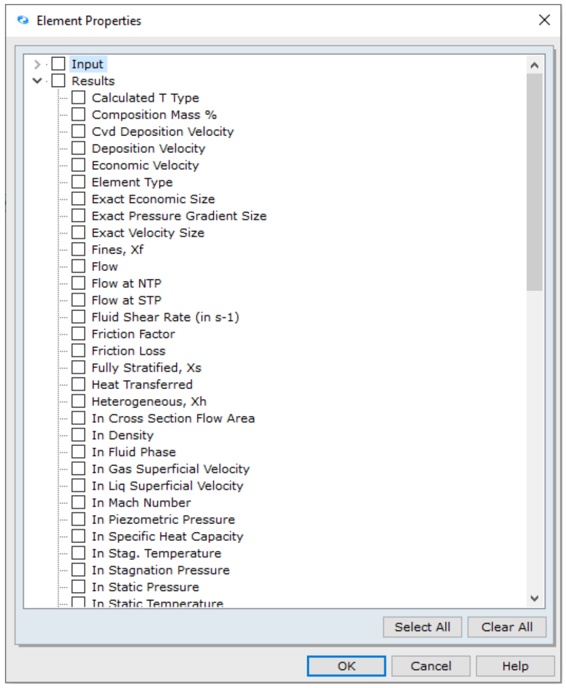



**Figure 52: Element Properties Dialogue Box.**

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

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

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

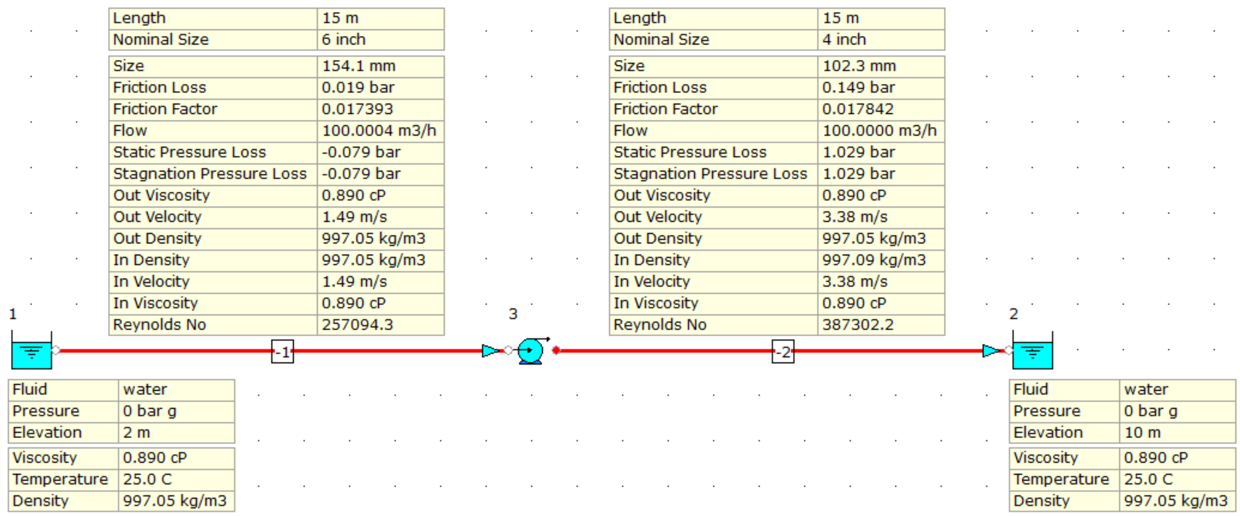



**Figure 53: Hydraulic Model with Pipe Properties.**

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).

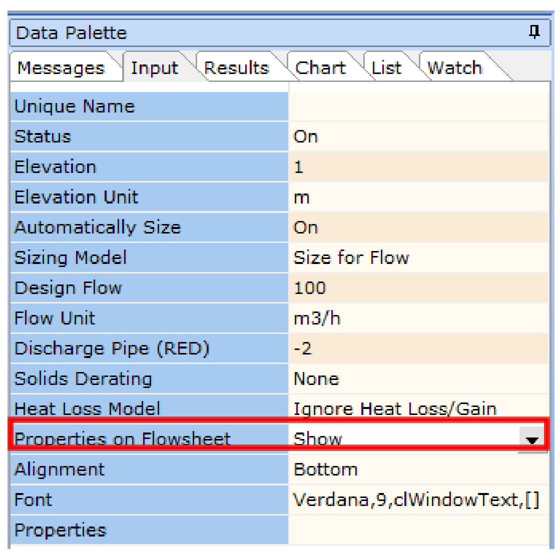



**Figure 54: Show Properties on Flowsheet.**

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

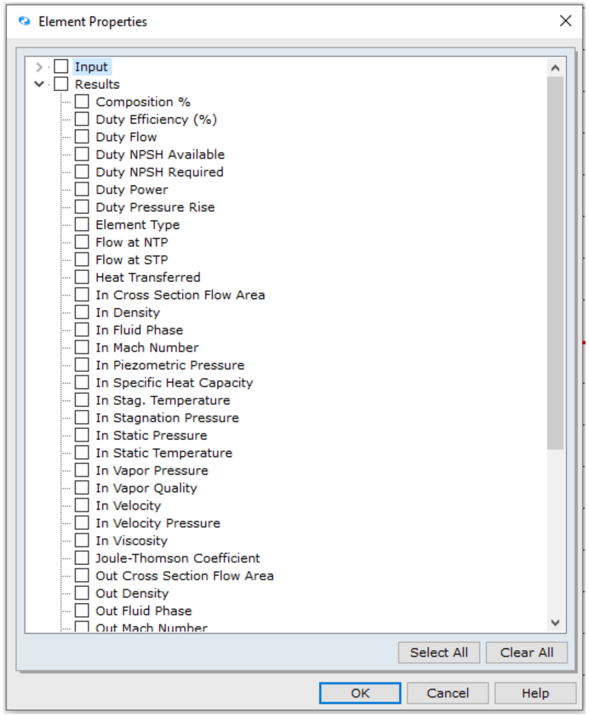



**Figure 55: Element Properties Dialogue Box.**

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

| Element Properties | |
|---|---|
| Input | Results |
| Design Flow | Duty Flow |
| Elevation | 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 Velocity |
| | Out Viscosity |

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

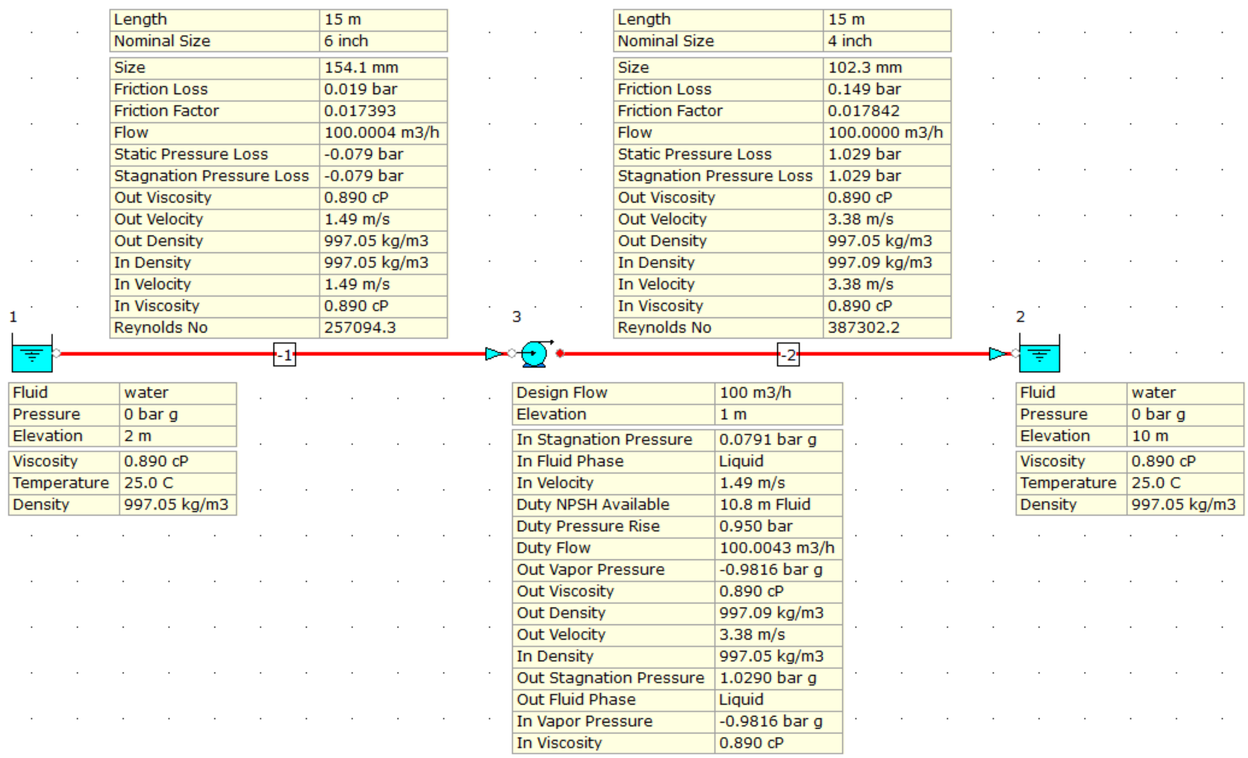



**Figure 56: Hydraulic Model with Pump Properties.**

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.

$Given:$

$P_1 = 0\ barg$

$P_2 = 0\ barg$

$z_1 = 2\ m$

$z_2 = 10\ m$

$Suction\ line\ size\ = 6"\ SCH\ 40$

$Discharge\ line\ size\ = 4"\ SCH\ 40$

$L_{-1} = 15.0\ m$

$L_{-2} = 15.0\ m$

$Volumetric\ Flow\ Rate,\ \dot{q} = 100\frac{m^3}{h}$

$Water\ at\ 25°C$

$Required$:

$Velocity,\ V_{-1} = V_1 =?$

$Velocity,\ V_{-2} = V_2 = ?$

$Reynolds\ Number,\ Re_{-1} = ?$

$Reynolds\ Number,\ Re_{-2} = ?$

$Darcy\ Friction\ Factor,\ f_{D_{-1}} = ?$

$Darcy\ Friction\ Factor,\ f_{D_{-2}} = ?$

$Pump\ Differential\ Head,\ W^{'}\ or\ \Delta h =?$

$Pump\ Differential\ Pressure,\ \Delta P_{Differential} =?$

$Friction\ loss_{-1} =-\ \Delta P_{-1} = ?$

$Friction\ loss_{-2} =-\ \Delta P_{-2} = ?$

$NPSH_{Available} = ?$

$Solution$:

$6"\ SCH\ 40,\ I.D. = D_{-1} = 154.1\ mm = 0.1541\ m$

$4"\ SCH\ 40,\ I.D. = D_{-2} = 102.3\ mm = 0.1023\ m$

$Density\ of\ Water\ at\ 25.0°C\ from\ FluidFlow\ Calculated\ Properties\ Database$

$\rho_{H_2O} = 997.05\ \frac{kg}{m^3}$

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

$\mu_{H_2O} = 0.890\ cP$

*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:*

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

$$\frac{\Delta P}{\rho} = 0\ \left(Constant\ pressure, P_1 = P_2\right)$$

$$F_{Fittings} = F_{Contraction} = F_{Expansion} = F_{Metering} = 0$$

$$F_{Line_{-1}} = h_{Line_{-1}} = \frac{4f_{F_{-1}}L_{-1}V^2_{-1}}{2D_{-1}g_c}$$

$$F_{Line_{-2}} = h_{Line_{-2}} = \frac{4f_{F_{-2}}L_{-2}V^2_{-2}}{2D_{-2}g_c}$$

$$\sum F = F_{Line_{-1}} + F_{Line_{-2}} = \frac{4f_{F_{-1}}L_{-1}V^2_{-1}}{2D_{-1}g_c} + \frac{4f_{F_{-2}}L_{-2}V^2_{-2}}{2D_{-2}g_c} = \frac{2f_{F_{-1}}L_{-1}V^2_{-1}}{D_{-1}g_c} + \frac{2f_{F_{-2}}L_{-2}V^2_{-2}}{D_{-2}g_c}$$

*Applying the above conditions to Mechanical Energy Balance equation:*

$$W' = \Delta z\frac{g}{g_c} + \frac{\Delta V^2}{2g_c} + 0 + F_{Line_{-1}} + F_{Line_{-2}}$$

$$W' = \left(z_2 - z_1\right)\frac{g}{g_c} + \frac{V_2^2 - V_1^2}{2g_c} + \frac{2f_{F_{-1}}L_{-1}V^2_{-1}}{D_{-1}g_c} + \frac{2f_{F_{-2}}L_{-2}V^2_{-2}}{D_{-2}g_c}$$

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

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

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

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

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

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

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

$Perry's\ Chemical\ Engineer's\ Handbook\ -\ 8th\ ed.$

$The\ Colebrook\ formula\ Equation\ (6\ -\ 38)$

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

$$\frac{1}{\sqrt{f_{F_{-1}}}} =- 4\log log\left[\frac{\epsilon}{3.7D_{-1}} + \frac{1.256}{Re_{-1}\sqrt{f_{F_{-1}}}}\right]$$

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

$Perry's\ Chemical\ Engineer's\ Handbook\ -\ 8th\ ed.$

$Table\ 6\ -\ 1\ Value\ of\ Surface\ Roughness\ for\ Various\ Materials$

$Commercial\ steel\ or\ wrought\ iron,\ \epsilon = 0.0457\ mm$

$Substitute\ the\ values\ of\ D,\ \epsilon,\ and\ Re.$

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

$$f_{F_{-1}} = 4.3038\times10^{-3}$$

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

$$f_{F_{-2}} = 4.3963\times10^{-3}$$

$Let\ us\ calculate\ for\ the\ value\ of\ Darcy\ friction\ factors$

$$f_{D_{-1}} = 4f_{F_{-1}} = 4\left(4.3038\times10^{-3}\right)$$

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

$$f_{D_{-2}} = 4f_{F_{-2}} = 4\left(4.3963\times10^{-3}\right)$$

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

$$\Delta z\frac{g}{g_c} = \left(z_2 - z_1\right)\frac{g}{g_c} = (10\ -\ 2)m\times\frac{9.80665\frac{m}{s^2}}{1\frac{kg-m}{N-s^2}} = 78.4532\frac{N-m}{kg}$$

$$\frac{\Delta V^2}{2g_c} = \frac{V_2^2-V_1^2}{2g_c} = \frac{\left(3.3795\frac{m}{s}\right)^2-\left(1.4894\frac{m}{s}\right)^2}{2\left(1\frac{kg-m}{N-s^2}\right)} = 4.6014\frac{N-m}{kg}$$

$$F_{Line_{-1}} = \frac{2f_{F_{-1}}L_{-1}V_{-1}^2}{D_{-1}g_c} = \frac{2\left(4.3038\times10^{-3}\right)(15\ m)\left(1.4894\frac{m}{s}\right)^2}{(0.1541\ m)\left(1\frac{kg-m}{N-s^2}\right)} = 1.8586\frac{N-m}{kg}$$

$$F_{Line_{-2}} = \frac{2f_{F_{-2}}L_{-2}V_{-2}^2}{D_{-2}g_c} = \frac{2\left(4.3963\times10^{-3}\right)(15\ m)\left(3.3795\frac{m}{s}\right)^2}{(0.1023\ m)\left(1\frac{kg-m}{N-s^2}\right)} = 14.7244\frac{N-m}{kg}$$

$$W^{'} = \Delta z\frac{g}{g_c} + \frac{\Delta V^2}{2g_c} + 0 + F_{Line_{-1}} + F_{Line_{-2}}$$

$$W^{'} = (78.4532\ +\ 4.6014\ +\ 1.8586\ +\ 14.7244)\frac{N-m}{kg}$$

$$W^{'} = 99.6376\frac{N-m}{kg} \times \frac{1\ kg}{9.80665\ N}$$

$$W^{'} = \Delta h = 10.1602\ m\ (Pump\ Differential\ Head)$$

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

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

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

*Let us calculate for the value of frictional losses*

$$Friction\ loss_{-1} = F_{Line_{-1}} = h_{Line_{-1}} = \frac{-\Delta P_{-1}}{\rho} = \frac{4f_{F_{-1}}L_{-1}V_{-1}^2}{2D_{-1}g_c}$$

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

$$Friction\ loss_{-1} =- \Delta P_{-1} = \frac{2\left(4.3038\times10^{-3}\right)(15\ m)\left(1.4894\frac{m}{s}\right)^2(997.05)}{(0.1541\ m)\left(1\frac{kg-m}{N-s^2}\right)} = 1853\ Pa$$

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

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

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

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

$$Friction\ loss_{-2} =- \Delta P_{-2} = \frac{2\left(4.3963\times10^{-3}\right)(15\ m)\left(3.3795\frac{m}{s}\right)^2(997.05)}{(0.1023\ m)\left(1\frac{kg-m}{N-s^2}\right)} = 14681\ Pa$$

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

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

$$NPSH_{Available} = \frac{g_c}{g}\left[\frac{P_{suction} - P^{sat}}{\rho}\right] = \frac{g_c}{g}\left[\frac{In\ Stagnation\ Pressure - In\ Vapor\ Pressure}{\rho}\right]_{Pump}$$

$$NPSH_{Available} = \frac{1\ kg}{9.80665\ N}\left[\frac{[0.0791\ barg-(-0.9816\ barg)]\times\frac{101325\ Pa}{1.01325\ bar}}{997.05\frac{kg}{m^3}}\right]$$

$$NPSH_{Available} = 10.8481\ m = 10,8481\ mm$$

**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% |
| $Pump\ Diff.\ Head,\ W'\ or\ \Delta h$ | m | 9.715 | 10.160 | 4.4780% |
| $Pump\ Diff.\ Pressure,\ \Delta P_{Di}$ | bar | 0.950 | 0.993 | 4.4262% |

| | | | | |
|---|---|---|---|---|
| $Friction\ loss_{-1}, -\Delta P_{-1}$ | 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.