FluidFlow

The Flow of Gas via Elevation Difference

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The Flow of Gas via Elevation Difference

Problem

Calculate the stagnation pressure loss, friction loss, flow rate, velocity, Reynolds number, and friction factor for a 20 m long 4" schedule 40 steel pipe transporting air at 25°C. The pipe inlet and outlet pressure shall be 1.0 barg. The pipe inlet elevation shall be 20 m and the outlet elevation of 10 m from grade.

Objective

The fluid will flow naturally from the source at a higher elevation to the sink at a lower elevation due to gravity (potential energy). Static head is the pressure resulting from a column of fluid acting under gravity. For compressible flow applications, changes in elevation are negligible compared to the other terms in the mechanical energy balance equation due to low-density values of gases.

In this example, you will build a model to illustrate the flow of gas via elevation difference or gravity.

This example includes the following tasks:

- Task 1 Add the Boundaries and Piping Component
- Task 2 Define the Boundaries, Fluid, and Piping
- 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 and Piping Component

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

FuidFlow v3.50 - (Flowsheet1)	– ø ×
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) 🞯 - 🖬 😭 🖄 🚊 🗇 🗴 🚓 🚓 🐴 🔍 🔍 80% 🔄 Fine 🔄 🖄 Galakte 🖄 🕃 - 🚸 💂 🔰 System International 👘 – 🟥 🗄 🔌 👷	
es '\Bundaries \Jundian' Boostes \Valvies \Controllers \Check Valves \General Resistances \Size Change \Relief Devices \Heat Exchangers \	
	Palette
Mess	ages Input Results Chart List Watch
· · · · · · · · · · · · · · · · · · ·	
s Bo Ortho Snap ON STP: Duxbury WASC TAPPI Whalley Criteria	

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	Pipes Boundaries Junctions Boosters						
⊡	🚈 🛱 नी 🦡 🖷 🧕						
13	Known or Assigned Pressure						
\square							

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).



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Ŧ								Ŧ
								·

Figure 3: Known Pressure Nodes.

4. This represents our pipe boundaries. We can now connect the boundaries 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 4).



Figure 4: Steel Pipe of Duct Icon.

To connect the boundaries, left mouse-click directly over the inlet boundary node (node 1) and again, left mouse-click directly over the outlet boundary node (node 2). Note, when you position the mouse selector above the boundary node 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.



Figure 5: Hydraulic Model.

6. 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 5, we can see that the inlet and outlet boundaries are assigned with User Number "1" & "2" respectively and the single pipe is assigned with User Number "-1". 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 6):





Figure 6: 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.

7. Save your flowsheet as 05-FF Gas via Elevation Difference.FF3

Task 2 – Define the Boundaries, Fluid, and Piping

The next step is to edit the default data for each of the nodes placed on the flowsheet (Boundaries, Fluid, and Piping). 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.

 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 7).



9. We can now edit the data entry for both nodes at once from the Input Inspector on the *Data Palette* (Figure 8).



Data Palette		Ф
Messages Ing	out 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 Ur	nit	с
Fluid		water
Fluid Type		Newtonian/NN-NonSettling
Properties on Fl	owsheet	Hide

Figure 8: Input Inspector.

10. 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 9). We have now successfully changed the pressure units for both nodes.

Data Polette 0					
Messeges Input Results Chart List Watch					
Unique Name					
Status	On				
Elevation	0				
Elevation Unit	m				
Pressure Model	Stagnotion Pressure				
Pressure	1				
Precoure Unit	atm 💌				
Temperature	atm ^				
Temperature Unit	bar a				
Huid	om Fluid a				
Fluid Type	ft Fluid a				
Properties on Flowsheet	ft Fluid q				
	ft Water a Y				

Figure 9: Pressure Units.

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

In this cell	Enter
Elevation	20
Temperature	25
Fluid	air



To change the default fluid water, left click on the field titled *Fluid* and a button with 3 dots will appear (Figure 10):

Data Palette 4				
Messages Input Results Chart List Watch				
Unique Name				
Status	On			
Elevation	20			
Elevation Unit	m			
Pressure Model	Stagnation Pressure			
Pressure	1			
Pressure Unit	bar g			
Temperature	25			
Temperature Unit	с			
Fluid	water			
Fluid Type	Newtonian/NN-NonSettling			
Properties on Flowsheet	Hide			

Figure 10: Fluid with 3 dots button.

Click the button and a Select Fluid dialog box will appear (Figure 11):

Select Fluid X					
<u>V</u> iew:	Show Chemi	ical Names	~		
Search:					
vinyl acet	ate		^		
vinyl acet	ylene				
vinyl bror	nide				
vinyl chlo	ride				
vinyl ethy	l ether				
vinyl fluo	ride				
vinyl formate					
vinvlcvclohexene					
vinvlidene chloride					
vinylidene difluoride					
Waferox					
Wafer-Ox 5					
wash syrup 76by					
water					
wet air 19	%		~		
		H2O			
	01	Canaal	Hala		
	UK	Cancel	нер		

Figure 11: Select Fluid Dialog Box.

This dialog box will allow us to access the fluid database (Figure 11). From the list of the available fluids, you may browse via scroll bar or search for the **air** via the search field. Select **air** and click **OK** to complete this change (Figure 12).



<u>V</u> iew:	Show Chemical Names	~			
Search:	air				
acetic a	cid solution 10%	^			
acetic a	nhydride				
acetone	1				
acetone	cyanohydrin				
acetonit	rile				
acetyl c	hloride				
acetylad	cetone				
acetylene					
acrolein					
acrylamide					
acrylic acid					
acrylonitrile					
adiponit	rile	_			
air					
air [by ı	mixture]	¥			
	Mixture				

Figure 12: Select Fluid Dialog Box.

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

Data Palette 🕴 🖡				
Messages Input Results Chart List Watch				
Unique Name				
Status	On			
Elevation	20			
Elevation Unit	m			
Pressure Model	Stagnation Pressure			
Pressure	1			
Pressure Unit	bar g			
Temperature	25			
Temperature Unit	с			
Fluid	air			
Fluid Type	Newtonian/NN-NonSettling			
Properties on Flowsheet	Hide			

Figure 13: Input Inspector at Node 1.

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

In this cell	Enter
Elevation	10



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

Data Palette 🛛 🗘				
Messages Input Results Chart List Watch				
Unique Name				
Status	On			
Elevation	10			
Elevation Unit	m			
Pressure Model	Stagnation Pressure			
Pressure	1			
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.

The operating pressure is already at 1 barg which is consistent with our specification for node 2. For the temperature and fluid inputs, we don't need to change it to 25°C and air, respectively. Note that FluidFlow will use the operating conditions of the higher elevation node 1 in calculating the fluid properties such as density, viscosity, thermal conductivity, etc.

13. Let us now edit the default 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.

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

In this cell	Enter
Length	20
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 16):



Data Polette		Ģ
Messages Input Real	uta (Chart (List (Watch)	
Unique Name		
Status	Un	
length .	20	
Length Unit	m	
Geometry	Cylindrical	
Use Database Size	Yes	
Nominal Size	2 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 = B36.10M 1.65mm = B36.10M 1.65mm = B36.10M 1.107mm = B36.10M 3.18mm = B36.10M 3.91mm = B36.10M 3.91mm = B36.10M 4.37mm = B36.10M 4.37mm = B36.10M 5.54mm	
 J/8 inch J/4 inch J/2 inch J/2 inch J/2 inch J/4 inch I 1/2 inch I 1/2 inch J/1 inch J/1 inch J/2 inch Z inch B36.10M 1.65mm B36.10M 1.07mm B36.10M 2.17mm B36.10M 3.18mm B36.10M 3.58mm B36.10M 3.91mm B36.10M 4.78mm B36.10M 4.78mm B36.10M 5.54mm 	
 > 1/4 inch > 3/8 inch > 1/2 inch > 3/4 inch > 1 inch > 1 1/4 inch > 1 1/4 inch > 1 1/2 inch > 1 1/2 inch > 2 inch = B36.10M 1.07mm = B36.10M 2.11mm = B36.10M 3.18mm = B36.10M 3.91mm = B36.10M 4.37mm = B36.10M 4.37mm = B36.10M 4.37mm = B36.10M 5.54mm 	
 J8 inch 1/2 inch J/4 inch 1 1/2 inch 2 inch 836.10M 1.65mm B36.10M 1.07mm B36.10M 1.07mm B36.10M 3.07mm B36.10M 3.93mm B36.10M 3.91mm B36.10M 4.37mm B36.10M 4.78mm B36.10M 4.78mm 	
 ↓ 1/2 inch ↓ 3/4 inch ↓ 1/4 inch ↓ 1/2 inch ↓ 1/2 inch ↓ 1/2 inch ♥ 2 inch ■ B36.10M 1.65mm ■ B36.10M 1.107mm ■ B36.10M 1.107mm ■ B36.10M 3.18mm ■ B36.10M 3.18mm ■ B36.10M 3.91mm ■ B36.10M 4.37mm ■ B36.10M 4.78mm ■ B36.10M 5.54mm 	
 > 3/4 inch > 1 inch > 1 1/2 inch > 2 inch > 2 inch > 2 inch = B36.10M 1.65mm = B36.10M 2.11mm = B36.10M 3.18mm = B36.10M 3.93mm = B36.10M 3.91mm = B36.10M 4.37mm = B36.10M 4.37mm = B36.10M 4.78mm = B36.10M 5.54mm 	
 > 1 inch > 1 1/4 inch > 1 1/2 inch ✓ 2 inch = B36.10M 1.65mm = B36.10M 1.07mm = B36.10M 2.11mm = B36.10M 3.77mm = B36.10M 3.58mm = B36.10M 3.58mm = B36.10M 3.78mm = B36.10M 4.77mm = B36.10M 4.78mm = B36.10M 5.54mm 	
 1 1/4 inch 1 1/2 inch 2 inch B36,10M 1.65mm B36,10M 1.07mm B36,10M 2.11mm B36,10M 2.11mm B36,10M 3.18mm B36,10M 3.18mm B36,10M 3.91mm B36,10M 4.97mm B36,10M 4.97mm B36,10M 4.78mm B36,10M 5.54mm 	
 1 1/2 inch 2 inch B36.10M 1.65mm B36.10M 1.07mm B36.10M 2.11mm B36.10M 2.77mm B36.10M 3.78mm B36.10M 3.98mm B36.10M 4.97mm B36.10M 4.97mm B36.10M 4.78mm B36.10M 5.54mm 	
 2 inh B36.10M 1.65mm B36.10M 11.07mm B36.10M 2.11mm B36.10M 2.77mm B36.10M 3.18mm B36.10M 3.98mm B36.10M 3.91mm B36.10M 4.37mm B36.10M 4.78mm B36.10M 4.78mm 	
- B36.10M 1.65mm - B36.10M 1.07mm - B36.10M 2.11mm - B36.10M 3.77mm - B36.10M 3.18mm - B36.10M 3.88mm - B36.10M 3.91mm - B36.10M 4.77mm - B36.10M 4.77mm - B36.10M 5.54mm	
- B36.10M 11.07mm - B36.10M 2.11mm - B36.10M 3.18mm - B36.10M 3.58mm - B36.10M 3.58mm - B36.10M 3.91mm - B36.10M 4.37mm - B36.10M 4.78mm - B36.10M 5.54mm	
- B36.10M 2.11mm - B36.10M 2.77mm - B36.10M 3.18mm - B36.10M 3.58mm - B36.10M 4.37mm - B36.10M 4.37mm - B36.10M 4.78mm - B36.10M 5.54mm	
- 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 3.18mm - B36.10M 3.58mm - B36.10M 3.91mm - B36.10M 4.37mm - B36.10M 4.78mm - B36.10M 5.54mm	
- B36.10M 3.58mm - B36.10M 3.91mm - B36.10M 4.37mm - B36.10M 4.78mm - B36.10M 5.54mm	
- B36.10M 3.91mm - B35.10M 4.37mm - B36.10M 4.78mm - B36.10M 5.54mm	
B36.10M 4.37mm B36.10M 4.78mm B36.10M 5.54mm	
B36.10M 4.78mm B36.10M 5.54mm	
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 **4 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.

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

Data Palette	д
Messages Input Results	Chart List Watch
Unique Name	
Status	On
Length	20
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 19: Input Inspector at Pipe Number "-1".



16. 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.

17. View the top portion of the user interface. The Units selector is on the middle portion (Figure 20):

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Pipes Boundaries Junctions Boosters Valves Controllers Check Valve	s General Resistances Size Change Relief Devices Heat Exchangers
///////////	

Figure 20: Unit Selector.

18. Click the drop-down menu to select a unit set. There are two default unit sets available: System International and US Basic (Figure 21).



Figure 21: Unit Selector Drop-Down Menu.

- 19. 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.
- 20. We can change our units by right mouse-clicking on the *Results* tab followed by selecting *Results Units* from the drop-down menu (Figure 22).

Data Polette	-
Mossages (Input	Resulta Chart List Watch
User Number	-1
Element Type	Meccagec
Static Pressure	Recuito
Stagnation Pre M	Chart
Friction Loss 🗸	Componenta List
Pressure Grad	Calculation Watch
Loss Correlatio	Cata Relation
5 Ze	
In Cross Sort	Component Defaults 74
In Stangation	Ely By Options P6
In Static Press	Visible Results 78
In Velocity Pre	Recuit Units F9
In Velocity	Calculation 2
In Stac. lemp	Enclosed 20
In Static Temp	Flowenect F3
In Density 🛷	Warning and Lints 10
In Viscosity	0.000 cP

Figure 22: Result Units.



21. Alternatively, you can select F9. This opens a new dialogue box per Figure 23.

	Preferred Units		Dec	. Pla	ices
Area	mm2	~	•	1	•
<u>D</u> ensity	kg/m3	~	•	2	۲
Elow	kg/s	~	•	4	F
Flow Coefficient Cv,Kv	usgpm/psi	~	•	3	۱.
Heat Transfer Coefficient	W/m2 C	~	•	5	•
<u>L</u> ength	m	~	•	2	•
NPSH	mm Fluid	~	•	1	۲
Pipe Si <u>z</u> e	mm	~	•	1	۲
Power	Watt	~	•	1	۲
Pressure/ <u>H</u> ead	Pa a	\sim	•	4	۲
Pressure/Head Drop	Pa	~	•	3	۲
Pressure Gradient	Pa/m	~	•	1	۲
Specific Heat Capacity	J/kg C	~	•	2	۲
Temperature	С	~	•	1	×
Velocity	m/s	~	•	2	•
Viscosity	cP	~	•	3	×

Figure 23: Set Result Units Dialogue Box.

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

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

23. The Set Result Units dialogue box should now look like the screenshot given below (Figure 24). Select **OK** to apply the changes.



General Gas Solids					
	Preferred Units		De	c. Pla	ices
Area	mm2	\sim	•	1	۲
<u>D</u> ensity	kg/m3	\sim	4	2	۲
Flow	ka/h	\sim	4	4	Þ
Flow <u>C</u> oefficient Cv,Kv	usgpm/psi	~	•	3	•
Heat Transfer Coefficient	W/m2 C	~	•	5	•
<u>L</u> ength	m	~	4	2	۲
NPSH	mm Fluid	~	4	1	۲
Pipe Si <u>z</u> e	mm	~	•	1	۲
Power	Watt	\sim	4	1	×
Pressure/ <u>H</u> ead	bar g	~	4	4	۲
Pressure/Head Drop	bar	\sim	4	3	×
Pressure Gradient	Pa/m	~	•	1	٠
Specific Heat Capacity	J/kg C	~	•	2	۲
Temperature	С	~	4	1	۲
Velocity	m/s	~	•	2	•
Viscosity	cP	~	•	3	×

Figure 24: Modified Set Result Units Dialogue Box.

24. 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 25).

9 File Edit View Database Options Tools Window Help	
🗋 💣 - 🖬 📸 🗄 💩 🛎 🖉 🚿 😳 🖹 🕅 🔍 🍳 80% 🔮 Hine 👘 🔛 🖾 🖉 🔂 🖉 🚦 Exotem International 👘	· 🔒 🗉 🧳 🔒
Tpos (Soundaries Quinctions (Boosters (Volves (Controllers (Check Volves (Control Resistances (Size Change)(tellef Devices (Heat E	Open Environment
//////////////	Save Environment
	Component Defaults F4
	Excel Columne F5
	Fly By Options F6
	Print Columna F7
1	Visible Iteaulta F8
	Result Unita F9

Figure 25: Save Environment Option.

25. The Save Environment dialogue box will appear (Figure 26).

📀 Save Env	vironment	×
Folder:	C:\Users\Public\Documents\Flite\FluidFlow3\Preferences\D	efault\3500
System	m International.ffs	
	BICHIS	
<u>F</u> ilename:		
Delete	Save Cancel	Help

Figure 26: Save Environment Dialogue Box.



26. On the Filename: section type Custom Unit 1 and click Save (Figure 27).

😒 Save Env	ironment	\times
Folder: Syster US Ba: Eilename:	C:\Users\Public\Documents\Flite\FluidFlow3\Preferences\Default\3500 n International.ffs sic.ffs Custom Unit 1	
Delete	Save Cancel Help	

Figure 27: Modified Save Environment Dialogue Box.

27. Now that we have successfully added our custom unit, it is now available in the unit set drop-down menu (Figure 28). Let us now use **Custom Unit 1** as our preferred unit set for this example.

🔹 🚰 Calculate 🔛 💁 🛞 💂 🕻 Custom Unit 1	-	• 🖪 🗉 🥠 🖕
Control Resistances Size Chang System International		xahangara
US Dasic		

Figure 28: Unit Set Drop-Down Menu.

28. 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.

29. Calculate the model using the *Calculate* button located at the top of the flowsheet (Figure 29):

So <u>File Edit View Database Options</u> Tools <u>W</u> indow <u>H</u> elp	
: 🗋 🚰 - 🖬 📬 : 🗄 🛕 🖳 🔎 🐇 🗈 🙈 👫 🔍 🔍 80%	🛛 🔹 Fine 🔹 🔀 Calculate 🔀 🖉 🖉 👷 System International 🔹 🔹 👔 🔛 🚸 💂
Pipes Boundaries Junctions Boosters Valves Controllers C	Check Valves General Resistances Size Change Relief Devices Heat Exchangers
////////////	

Figure 29: Calculate Button.



30. Check the converged hydraulic model in the flowsheet. The blue arrowhead shows that the flow direction is from the higher elevation node 1 to the lower elevation node 2. Also, check if the pipe is highlighted in **RED**, indicating that we have a warning message associated with the pipe element (Figure 30).



Figure 30: Converged Hydraulic Model

Note: Make sure that the **RED** Show or Hide Warnings Highlight button is selected in the *Flowsheet Toolbar* (Figure 31):

Show or Hide Warnings Highlight

Figure 31: Show or Hide Warnings Highlight Button.

31. Select the *Messages* tab on the *Data Palette*, we can view all warnings for the model including a description of each (Figure 32). The converged hydraulic model has no warnings. Therefore, we can now proceed with the analysis of the results.

Data Polette	Ģ
Messages (Input Results (Chart Ust (Watch	
Description	

Figure 32: 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.

32. 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 33 provides an overview of these results.



				1
	Data Palette 🔶		¥	J.
	Messages Input Results	Chart List V	/atch	
	User Number	-1		
	Element Type	Steel Pipe, Due	t or Tube	
	Flow	485.3885	kg/h	
	Flow at STP	396.0	m3/h	
	Flow at NTP	375.3	m3/h	
	Static Pressure Loss	0.000	bar	
	Stagnation Pressure Loss	0.000	bar	
	Friction Loss	0.002	bar	
	Pressure Gradient	11.5	Pa/m	
	Loss Correlation	Duxbury		
	Economic Velocity	9.01	m/s	Surrented Economic Dire C
	Exact Economic Size	89.9	mm	- Suggested Economic Pipe Ø.
_	Size	102.3	mm	- Actual I.D. of 4 Sch. 40 Pipe.
	In Fluid Phase	Gas or Vapor		
	In Cross Section Flow Area	8219.4	mm2	
	In Stagnation Pressure	1.0000	bar g	
The "In" values	In Static Pressure	0.9994	bar g	
represent the calculated	In Velocity Pressure	0.001	bar	
conditions at the	In Velocity	6.97	m/s	
pipe Inlet.	In Mach Number	0.02		
	In Stag. Temperature	25.0	С	
	In Static Temperature	25.0	С	
	In Density	2.35	kg/m3	
	In Viscosity	0.018	сP	
L. L.	In Specific Heat Capacity	1007.47	J/kg C	
_	Joule-Thomson Coefficient	0.385	C/bar	
	Out Fluid Phase	Gas or Vapor		
	Out Cross Section Flow Area	8219.4	mm2	
	Out Stagnation Pressure	1.0000	bar g	
The #Out# veloce	Out Static Pressure	0.9994	bar g	
represent the colculated	Out Velocity Pressure	0.001	bar	
conditions at the	Out Velocity	6.97	m/s	
nine Outlet	Out Mach Number	0.02		
pipe outlet.	Out Stag. Temperature	25.0	С	
	Out Static Temperature	25.0	С	
	Out Density	2.35	kg/m3	
	Out Viscosity	0.018	cP	
Ĺ	Out Specific Heat Capacity	1007.47	J/kg C	
	Composition Mass %	air	100.0%	
	Reynolds No	91349.0		
	Friction Factor	0.020530		

Figure 33: Calculated Results.

33. 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 gas system, we are only interested in the Gas Limits (Figure 34).



Min. Pipe Velocity		0.5		
Max. Pipe Velocity		200		
Velocity		m/s		
Min. Opening Control V	alve (%)	30		
Max. Opening Control \	/alve (%)	85		

Figure 34: Warning and Hints: Gas Limits.

- 34. As we can see in Figure 33, the actual flowing velocity of the fluid is 6.97 m/s which is within the 0.5 200 m/s range for the minimum and maximum pipe velocity (Figure 34). The high-velocity warning is enunciated once the actual flowing velocity is higher than the maximum velocity level set in our warnings (200 m/s See Figure 34).
- 35. 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 33) 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 of the system.
- 36. We have established the pressure loss across the pipe element in this system and that the total stagnation pressure loss will be;

Stagnation Pressure at inlet boundary (Node 1):	1.00 barg.
Stagnation Pressure at outlet boundary (Node 2):	1.00 barg.
Stagnation Pressure Loss:	0.000 bar.

We know this is correct since we had an inlet pressure of **1.00 barg** and outlet pressure of **1.00 barg** which gives us a difference of **0.000 bar** (Figure 33). Since the stagnation pressure for inlet and outlet pressure points are both 1 bar gauge, we cannot rely on the pressure difference as a driving force for the gas to flow. Therefore, we will rely on the 10 meters elevation difference between the inlet and outlet boundaries, to drive the gas to flow via gravity.

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

Parameter	Value
Flowrate	485 kg/h
Reynolds Number	91349
Darcy Friction Factor	0.02053
Friction loss	0.002 bar



Note that for gas flow applications, changes in elevation are negligible. The density of gases is relatively low such that the static head term, of the mechanical energy balance equation for a gas system, does not significantly contribute. This is evident in the small value of the calculated flow rate, and frictional loss, across the 20-m pipe length, in our example.

38. Note that we can improve the presentation of our model by selecting the pipe 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 35).

Data Palette 4								
Messages Input Results Chart List Watch								
Unique Name								
Status	On							
Length	20							
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]	3							
Draw Color	clRed							
Properties on Flowsheet	Hide							

Figure 35: Modified Draw Thickness and Draw Color.

39. The hydraulic model should now look like the screenshot given below (Figure 36).



Figure 36: Hydraulic Model with Modified Draw Thickness and Draw Color.

40. 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 37).



Data Palette 🕴 🗘						
Messages Input Results	Chart List Watch					
Unique Name						
Status	On					
Elevation	10					
Elevation Unit	m					
Pressure Model	Stagnation Pressure					
Pressure	1					
Pressure Unit	bar g					
Temperature	15					
Temperature Unit	с					
Fluid	water					
Fluid Type	Newtonian/NN-NonSettling					
Properties on Flowsheet	Show 👻					
Alignment	Bottom					
Font	Verdana,9,clWindowText,[]					
Properties						

Figure 37: Show Properties on Flowsheet.

41. Now we will select the field titled *Properties* from the Input list. An *Element Properties* dialogue box will appear (Figure 38):



Figure 38: Element Properties Dialogue Box.

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

Element Properties	
Input	Results
Elevation	Composition Mass %
Pressure	Density
	Temperature
	Viscosity



1										•					•	2		
=						-	1									d <mark>∵</mark>		
Pressure	1 barg															Pressure	1 barg	
Elevation	20 m															Elevation	10 m	
Composition Mass %	air=100.0%	· ·	·				·		·	•	·	•	•	·	•	Composition Mass %	air=100.0%	
Viscosity	0.018 cP															Viscosity	0.018 cP	
Temperature	25.0 C	•	•	•	•	•	•	•	·	•	•	•	•	•	•	Temperature	25.0 C	
Density	2.35 kg/m3	۱.														Density	2.35 kg/m3	

43. The hydraulic model should now look like the screenshot given below (Figure 39).

Figure 39: Hydraulic Model with Inlet and Outlet Boundary Properties.

44. Now let us show the properties of the pipe. Left mouse-click on the pipe number "-1" and from the *Input Inspector*, change the field titled *Properties on Flowsheet* from *Hide* to *Show* (Figure 40).

Data Palette 🎝						
Messages Input Results	Chart List Watch					
Unique Name						
Status	On					
Length	20					
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]	3					
Draw Color	clRed					
Properties on Flowsheet	Show 👻					
Alignment	Bottom					
Font	Verdana,9,clWindowText,[]					
Properties						

Figure 40: Show Properties on Flowsheet.

45. Now we will select the field titled *Properties* from the Input list. An *Element Properties* dialogue box will appear (Figure 41):



Selement Properties			×
> Input			^
V 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			
Eluid Shear Rate (in s-1)			
Eriction Factor			
Eriction Loss			
- Fully Stratified Xe			
Heat Transferred			
In Cross Section Flow Area			
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
L	OK	Cancel	Halp
	UN	Cancel	neip



46. Place a checkmark in the box for the following parameters and click **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					



47. The hydraulic model should now look like the screenshot given below (Figure 42).

	1						•	•	•		•	•	2					
	=				- 1								Ŧ					
	Pressure	1 barg		Length	20 m								Press	ure			1 barg	
	Elevation	20 m		Nominal Size	4 inch								Elevat	tion			10 m	
	Composition Mass %	air=100.0%		Size	102.3 mm								Comp	ositior	Mass	: %	air=10	0.0%
	Viscosity	0.018 cP		Friction Loss	0.002 bar								Visco	sitv			0.018	cP
	Temperature	25.0 C		Friction Factor	0.020530	•				•			Tempe	erature			25.0 C	
	Density	2.35 ka/m3		Flow	485.3885 kg/h								Densi	tv			2.35 k	o/m3
·	,			Out Viscosity	0.018 cP	•	•	•	•	•	•	•		-/	•			
				Out Velocity	6.97 m/s													
·			•	Out Density	2.35 kg/m3	•	•	•	•	•	•	•	•	•	•	·	•	•
				In Density	2.35 kg/m3													
•			•	In Velocity	6.97 m/s	•						•	•	•	•	·	•	
				In Viscosity	0.018 cP													
•		• •	•	Reynolds No	91349.0	•	•	•	•	•	•	•	•	•	•	•	•	•

Figure 42: Hydraulic Model with Pipe Properties.

48. 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:

 $P_1 = 1.0 \ barg$ $P_2 = 1.0 \ barg$ $z_1 = 20 \ m$ $z_2 = 10 \ m$ $4" \ SCH \ 40$ $L = 20.0 \ m$ *Air at* $T = 25^{\circ}$ C = 298.15 K

Required:

Mass Flow Rate, $\dot{m} = ?$

Volumetric Flow Rate, $\dot{q} = ?$



Velocity, V = ?Reynolds Number, Re = ?Darcy Friction Factor, $f_D = ?$ Friction loss = ?

Solution:

 $z_1 = 20 m$ $z_2 = 10 m$ 4" SCH 40, I. D. = 102. 3 mm = 0. 1023 m

Density of Air at 25.0°C, 1.1 barg, 1.0 barg from FluidFlow Calculated Properties Database

$$\rho_{Air_{in/out}} = 2.35 \frac{kg}{m^3}$$

Viscosity of Air at 25.0°C, 1.1 barg, and 1.0 barg from FluidFlow Calculated Properties Database $\mu_{Air_{in/out}} = 0.018 cP$

For compressible fluids in which the pressure drop is relatively low and the density and velocity do not change appreciably, the flow may be treated as incompressible. Thus, equations used in incompressible calculations can be applied in our example.

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:

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

Let us simplify the following terms in the Mechanical Energy Balance Equation

$$W = 0$$
 (No compressor)
 $\frac{\Delta V^2}{2g_c} = 0$ (Constant cross – sectional area, $V_1 = V_2$)



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

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

$$\sum F = F_{Line} = h_{Line} = \frac{4f_F LV^2}{2Dg_c}$$

Applying the above conditions to Mechanical Energy Balance equation:

$$0 = \Delta z \frac{g}{g_c} + 0 + 0 + \frac{4f_F L V^2}{2Dg_c}$$
$$0 = (z_2 - z_1) \frac{g}{g_c} + \frac{4f_F L V^2}{2Dg_c}$$
$$(z_1 - z_2) \frac{g}{g_c} = \frac{2f_F L V^2}{Dg_c}$$

Since f_F and V are still unknown, let us arrange the equation and put it on the left - hand side

$$f_F V^2 = \frac{D(z_1 - z_2)g}{2L} = \frac{(0.1023 \, m)(20 - 10) \, m \left[9.80665 \frac{m}{s^2}\right]}{2(20.0 \, m)}$$
$$f_F V^2 = 0.2508050738 \rightarrow Equation 1$$

Let us now solve for the value of the Reynolds number. Since V is still unknown let us represent it as variable

$$Re = \frac{DV\rho}{\mu}$$

$$Re = \frac{(0.1023 m)(V) \left(2.35 \frac{kg}{m^3}\right)}{0.018 cP \times \frac{Pa-s}{1000 cP}}$$

 $Re = \frac{80135}{6}V \rightarrow Equation 2$

Perry's Chemical Engineer's Handbook – 8th ed.

The Colebrook formula Equation (6 - 38)

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

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 and ϵ

$$\frac{1}{\sqrt{f_F}} = -4\log\log\left[\frac{0.0457\,mm}{3.7(102.3\,mm)} + \frac{1.256}{Re\sqrt{f_F}}\right] \rightarrow Equation 3$$

Trial and Error (Iteration)

Trial 1

Step 1: Assume the value of f_F between 0.003 - 0.006 and solve for the value of V

using Equation 1.

 $f_F V^2 = 0.2508050738 \rightarrow Equation 1$

Assume $f_F = 0.005$

$$V = \sqrt{\frac{0.25080507385}{0.005}}$$
$$V = 7.0824 \frac{m}{s}$$

Step 2: Substitute the calculated value of V to Equation 2.

$$Re = \frac{80135}{6} V \rightarrow Equation 2$$

$$Re = \frac{80135}{6} \left(7.0824 \frac{m}{s}\right)$$

$$Re = 94591.354$$

Step 3: Substitute the value of Re to Equation 3 and calculate the value of $f_{\rm F}$.

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{\text{Re}\sqrt{f_F}} \right] \rightarrow Equation 3$$
$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{94591.354\sqrt{f_F}} \right]$$
$$f_F = 5.0659 \times 10^{-3}$$

Step 4: Compare the assumed value of f_F to the calculated value.

$$0.005 \neq 5.0659 \times 10^{-3}$$
$$f_{F, assumed} \neq f_{F, calculated}$$



Repeat Steps 1 - 4 until the value of $f_{F, assumed} = f_{F, calculated}$

Trial 2:

Step 1: Use the calculated value of f_F from the previous trial and solve for the value of V

using Equation 1.

$$f_F V^2 = 0.2508050738 \rightarrow Equation 1$$

Assume $f_F = 5.0659 \times 10^{-3}$

$$V = \sqrt{\frac{0.2508050738}{5.0659 \times 10^{-3}}}$$
$$V = 7.0362 \ \frac{m}{s}$$

Step 2: Substitute the calculated value of V to Equation 2.

$$Re = \frac{80135}{6} V \rightarrow Equation 2$$

$$Re = \frac{80135}{6} \left(7.0362 \ \frac{m}{s}\right)$$

$$Re = 93974.3145$$

Step 3: Substitute the value of Re to Equation 3 and calculate the value of $f_{\rm F}$.

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \, mm}{3.7(102.3 \, mm)} + \frac{1.256}{Re\sqrt{f_F}} \right] \rightarrow Equation 3$$
$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \, mm}{3.7(102.3 \, mm)} + \frac{1.256}{93974.3145\sqrt{f_F}} \right]$$
$$f_F = 5.0706 \times 10^{-3}$$

Step 4: Compare the assumed value of $f_{_F}$ to the calculated value.

5. 0659×10⁻³≠5. 0706×10⁻³
$$f_{F, assumed} \neq f_{F, calculated}$$

Repeat Steps 1 - 4 until the value of $f_{F, assumed} = f_{F, calculated}$



Trial 3:

Step 1: Use the calculated value of f_{F} from the previous trial and solve for the value of V

using Equation 1.

 $f_F V^2 = 0.2508050738 \rightarrow Equation 1$ Assume $f_F = 5.0706 \times 10^{-3}$

 $V = \sqrt{\frac{0.2508050738}{5.0706 \times 10^{-3}}}$ $V = 7.0330 \frac{m}{s}$

Step 2: Substitute the calculated value of V to Equation 2.

$$Re = \frac{80135}{6} V → Equation 2$$

$$Re = \frac{80135}{6} (7.0330 \frac{m}{s})$$

$$Re = 93931.5758$$

Step 3: Substitute the value of Re to Equation 3 and calculate the value of $f_{\rm F}$.

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{\text{Re}\sqrt{f_F}} \right] \rightarrow Equation 3$$
$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{93931.5758\sqrt{f_F}} \right]$$
$$f_F = 5.0709 \times 10^{-3}$$

Step 4: Compare the assumed value of f_F to the calculated value.

$$5.0706 \times 10^{-3} \neq 5.0709 \times 10^{-3}$$
$$f_{F, assumed} \neq f_{F, calculated}$$

Repeat Steps 1 - 4 until the value of $f_{F, assumed} = f_{F, calculated}$

Trial 4:

Step 1: Use the calculated value of f_F from the previous trial and solve for the value of V



using Equation 1.

$$f_F V^2 = 0.2508050738 \rightarrow Equation 1$$

Assume $f_F = 5.0709 \times 10^{-3}$

$$V = \sqrt{\frac{0.2508050738}{5.0709 \times 10^{-3}}}$$

$$V = 7.0328 \frac{m}{s}$$

Step 2: Substitute the calculated value of V to Equation 2. $Re = \frac{80135}{6} V \rightarrow Equation 2$ $Re = \frac{80135}{6} \left(7.0328 \frac{m}{s}\right)$ Re = 93928.9047

Step 3: Substitute the value of Re to Equation 3 and calculate the value of f_F .

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{\text{Re}\sqrt{f_F}} \right] \rightarrow Equation 3$$

$$\frac{1}{\sqrt{f_F}} = -4 \log \log \left[\frac{0.0457 \text{ mm}}{3.7(102.3 \text{ mm})} + \frac{1.256}{93928.9047\sqrt{f_F}} \right]$$

$$f_F = 5.0709 \times 10^{-3}$$

Step 4: Compare the assumed value of f_F to the calculated value.

5.
$$0709 \times 10^{-3} = 5.0709 \times 10^{-3}$$

 $f_{F, assumed} = f_{F, calculated}$

Stop the iteration.

Summary of Iteration

Trial	$f_{_{F,\ assumed}}$	V calculated	$Re_{calculated}$	$f_{_{F,calculated}}$
	0.005	7.0824	94591.3540	5.0659×10^{-3}
2	5.0659×10^{-3}	7.0362	93974.3145	5.0706×10^{-3}



3	5.0706×10^{-3}	7.0330	93931.5758	5.0709×10^{-3}
4	5.0709×10^{-3}	7.0328	93928. 9047	5.0709×10^{-3}

Therefore

$$f_F = 5.0709 \times 10^{-3}$$

$$V = 7.0328 \frac{m}{s}$$

Re = 93928.9047

Calculate for the value of Darcy friction factor, $f_{\rm D}$

$$f_D = 4f_F = 4(5.0709 \times 10^{-3})$$

 $f_D = 0.0203$

Calculate for the value of friction loss

 $\begin{aligned} Friction \ Loss \ &= \ F_{Line} = h_{Line} = \frac{-\Delta P}{\rho} = \frac{4f_{F}LV^{2}}{2Dg_{c}} \\ Friction \ Loss \ &= - \ \Delta P \ = \frac{2f_{F}LV^{2}\rho}{Dg_{c}} \\ Friction \ Loss \ &= - \ \Delta P \ = \frac{2(5.0709 \times 10^{-3})(20 \ m)(7.0328\frac{m}{s})^{2}(2.35\frac{kg}{m^{3}})}{(0.1023 \ m)(1\frac{kg-m}{N-s^{2}})} \ &= \ 230.\ 4591 \ Pa \\ Friction \ Loss \ &= - \ \Delta P \ = \ 230.\ 4591 \ Pa \ Pa \times \frac{1.01325 \ bar}{101325 \ Pa} \\ Friction \ Loss \ &= - \ \Delta P \ = \ 0.\ 002 \ bar \end{aligned}$

Calculate for the value of volumetric flow rate, q $\dot{q} = VS = V\left(\frac{\pi}{4}D^2\right) = 7.0328 \frac{m}{s} \left[\left(\frac{\pi}{4}\right)(0.1023 m)^2\right] \left[\frac{3600 s}{1 h}\right]$ $\dot{q} = 208.0999 \frac{m^3}{h} Calculate for the value of volumetric flow rate, \dot{q}$ $\dot{m} = \rho_{Air}VS = \rho_{Air}V\left(\frac{\pi}{4}D^2\right) = \left(2.35 \frac{kg}{m^3}\right) \left(7.0328 \frac{m}{s}\right) \left[\left(\frac{\pi}{4}\right)(0.1023 m)^2\right] \left[\frac{3600 s}{1 h}\right]$ $\dot{m} = 489.0348 \frac{kg}{h}$

Results Comparison:



Description	Unit	FluidFlow Results	Hand Calculation	% Difference			
	kg/h	485	489	0.8214%			
Volumetric Flow Rate, q	m³/h	206	208	0.9662%			
Velocity, V	m/s	6.97	7.03	0.8571%			
Reynolds Number, Re	-	91349	93929	2.7850%			
Darcy Friction Factor, f	-	0.0205	0.0203	0.9804%			
Friction loss	Bar	0.002	0.002	0%			

Commentary:

The results compare very well with the hand calculation.