LINE HYDRAULICS USING DWSIM:

A FREE AND OPEN-SOURCE CHEMICAL PROCESS SIMULATOR

BY

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PREFACE

The manual “Line Hydraulics Using DWSIM” presents a set of Line Sizing exercise using a free and open-source chemical process simulator “DWSIM” and can be utilized to establish process simulation laboratory as part of undergraduate chemical engineering degree or in allied degree curriculum. The problem statements are of intermediate level.

Prerequisite

- Must know about DWSIM UI/UX.
- Flow sheeting in DWSIM
- Selection of Thermodynamic Packages.
- Manipulating variables

Thanks

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P.E. O&G

Disclaimer

All the exercises are strictly restricted to learning only and not meant to be used in real world application.

PROCESS SIMULATION USING DWSIM: A FREE AND OPEN-SOURCE CHEMICAL PROCESS SIMULATOR

PREAMBLE

DWSIM is an open-source CAPE-OPEN compliant chemical process simulator. It features a Graphical User Interface (GUI), advanced thermodynamics calculations, reactions support and petroleum characterization / hypothetical component generation tools. DWSIM can simulate steady-state, vapor–liquid, vapor–liquid-liquid, solid–liquid and aqueous electrolyte equilibrium processes and has built-in thermodynamic models and unit operations (https://en.wikipedia.org/wiki/DWSIM). It is available for Windows, Linux and Mac OS.

The objective of the course is to create awareness of the open-source process simulator “DWSIM” among prospective graduates and practicing process engineers. The course will cover Intermediate aspects of create flow sheet in DWSIM and simulation of simple Pressure changing module like pipe segment

Target Audience

- Junior Interns in Process Firms
- III / Final year B. Tech. Chemical Engineering students
- M. Tech. Chemical Engineering students
- Practicing Process Engineers

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1 BACKGROUND

Line sizing by the Process department is one of the most important and critical activities for any project. Line size is determined with proper sizing calculations considering various parameters.

Purpose of Line Sizing

The main purpose of line sizing are:

- The purpose of line sizing (for common, water-like liquids, gases, and applications) is to fill in appropriate data on P&ID's, datasheets, and line lists
- To determine pump head requirements
- To meet design process parameters such as flow, velocity & pressure.

Factors affecting Line sizing decisions

Line sizing decisions are affected by:

1. Economics:

Line sizing decisions have economic impacts, including:

- cost of pipe
- cost of pipe supports
- operating pressure/power requirements

Liquid lines that are sized smaller will require a larger system supply pressure (due to higher friction losses), and possibly a larger pump and pump motor, increasing equipment capital cost and operating cost. Another factor to consider is the cost of the piping (including valves). The difference of the capital cost of ½" to ¾" piping is negligible, however, the cost of 3" to 2" piping is significant. Therefore, line sizing involves multiple economic factors, as well as other impacts.

2. Effect of Velocity/Turbulence in Pipeline Sizing:
- Incompressible fluids (air steam, nitrogen, etc.), the only design concern is to avoid sonic velocity (typically above 100 ft/sec). Usually, pressure drop guidelines result in pipe size selections that avoid sonic velocity.
- In non-sanitary liquid applications, velocity and turbulence are typically not a concern, unless slurry flow is present.
- For sanitary, non-compressible applications (our most frequent designs), velocity and turbulence are concerns. It is necessary to maintain a fully turbulent flow to avoid stagnant areas in the piping system that can promote bacterial growth.
3. Pressure Drop Effects for Line Sizing:
- The effect of pressure drop within a system is closely correlated to the economics of the system. Smaller pipe sizes result in larger pressure drop requirements; economic considerations require a balance between pipe size and pumping/power requirements to overcome pressure losses through the system.
4. Impact of Line Holdup in Pipe Sizing:

- In the biopharma industry, certain product liquids may have exceedingly high value, and the holdup in piping systems may be a primary concern. In addition to minimizing the length of piping systems and the recovery capabilities (air blows, sloped piping, etc.) of the piping systems, a smaller line size may be chosen to further minimize the loss potential of the liquid held up in the line. This becomes the governing criterion for sizing even though pressure drop exceeds the recommended range.

5. Space requirements for Line Sizing:

- Typically, space requirements are not a significant concern in the biopharma industry since most pipe sizes are less than 6 inches in diameter. Space may be a concern when existing pipe racks are used, where areas are tightly piped, or with gravity drainage systems. Interaction with the piping designer will identify critical areas where space is a consideration.

6. Effect of Expansion Effects in Line Sizing:

- Header system sizing should consider the possibility of plant expansion. The incremental cost of a larger pipe size will avoid many headaches down the road if expansion is a distinct possibility.
- Sizing of sanitary water loops must critically consider expansion possibilities, since oversizing the supply loop may reduce the velocity below the acceptable values to maintain full turbulence. Often, the supply pump needs to be oversized as well as the header to account for expansion. This oversizing should only be done if expansion is a distinct probability.

7. Line Sizing based on Equipment Nozzle Connections:

- Equipment nozzle connections for piping tie-ins are typically undersized when compared to the recommended pipe size. Be sure to perform the sizing calculation, select the appropriate pipe size, and, if required use reducers to connect the pipe to the equipment nozzle.

Steps in Line sizing procedures

I. Step 1 – Assume line size
II. Step 2 – Calculate velocity by $v = Q/A$
III. Step 3 – Calculate the pressure drop by the proper method.
IV. Step 4 – Check whether calculated velocity & pressure drop falls within recommended ranges.
   - If YES, then select the line size
   - If NO, then selects a new line size and repeat steps 2 to 4.

Recommended velocities & max ΔP for Line Sizing:

Sr. No	Types of Service	Velocity (m/sec)	Maximum ΔP Kg /cm^2/100m
1	General Recommendation	1.5 – 4.6	0.92
2	Pump Suction		

	– Boiling Liquid	0.6 – 1.8	0.115
	– Non – Boiling Liquid	1.2 – 2.4	0.23
3	Pump Discharge		
	– 0 – 57 m^3 / hr	1.8 – 2.4	1.38
	– 57 – 159 m^3 / hr	2.4 – 3.0	0.92
	– >159 m^3 / hr	3.0 – 4.6	0.46
4	Bottom Outlet	1.2 – 1.8	0.14
5	Reboiler Trapout	0.3 – 1.2	0.035
6	Liquid from Condenser	0.9 – 1.8	0.11
7	Liquid to chillers	1.2 – 1.8	
8	Refrigerant Lines	0.6 – 1.2	0.09
9	Gravity Lines	0.2 – 0.5	0.04
10	Drain Lines	0.5 – 1.2	
11	Boiler feed	2.4 – 4.6	
12	Liquid with suspended solids	0.9	

2 LINE HYDRAULICS

Objective

Find the pressure drop for the given problem statement

Data

Figure 1 Problem Statement

DWSIM Blocks Used

- Pipe segment
- Material Stream
- Indicators (Digital or Analog)

Procedure

1. Start a new DWSIM Simulation (DWSIM VER 8.2 - CLASSIC UI). Click on “New steady state Simulation” as a template for new simulation
2. The simulation configuration window will be opened. It shows a specification page. Add components required to solve the problem statement. In the present case, add water. Ensure all components are added from the same property database. For instance, in this case, both components are added from “ChemSep” database.
3. Specify the thermodynamic package as Stea m table (IAPWA-IF97).
4. Customize the system of units for the simulation and click “Next”.
5. The flow sheeting section of simulation window will be opened. First, let provide input and output streams for the unit operation to be performed. Drag and drop two Material streams available at the right, in the object palette. Rename them stream as “Inlet-Stream “and “Outlet Stream”.

6. On clicking the “Inlet Stream” stream, general information about the stream will be displayed on the left side of screen. Specify the feed compositions, temperature, and pressure for the inlet streams. Once credentials are specified for the inlet streams, the color of stream turns blue.

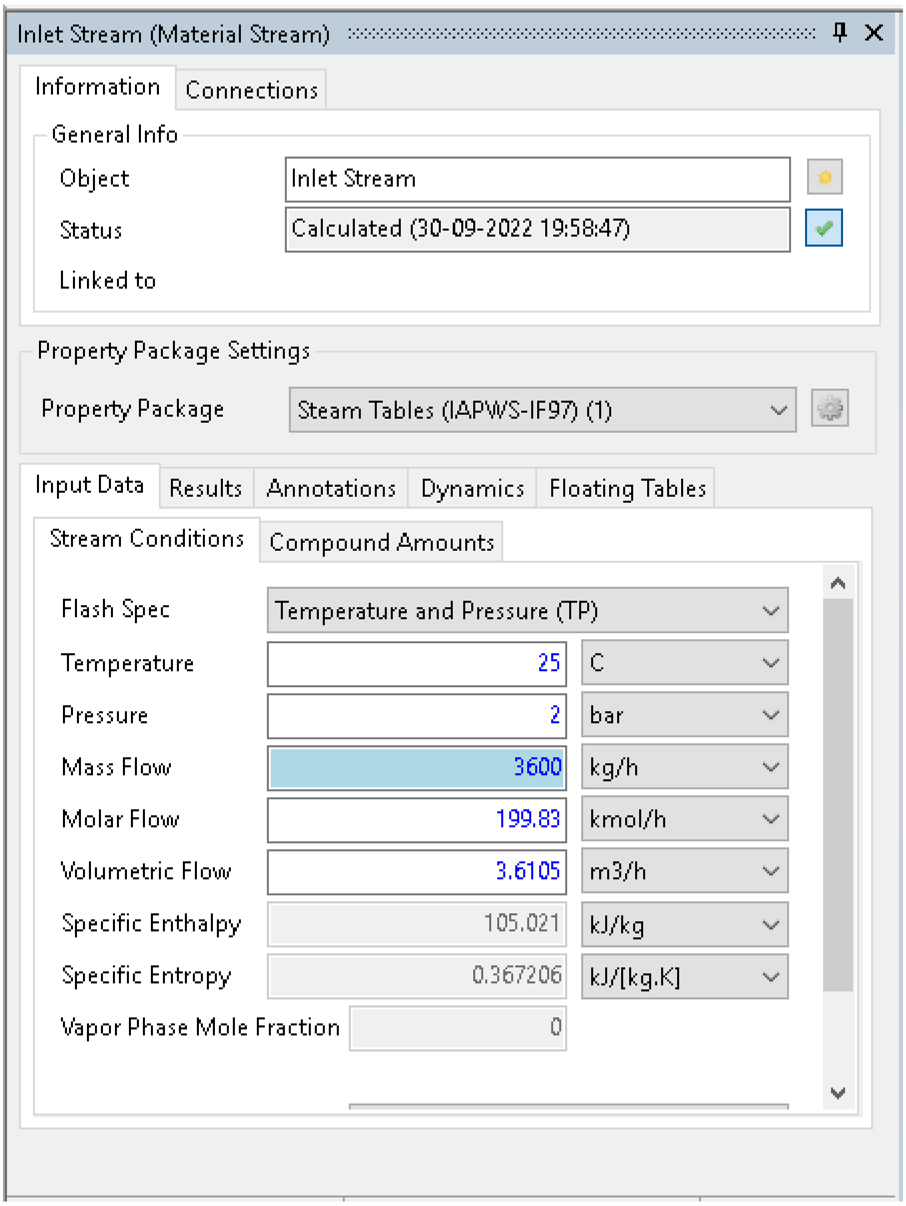

Figure 2 Inlet stream Specs

7. Below the Unit Operation tab on left, locate the pipe segment block. Drag and drop into the flow sheet. Rename it as “Line of 4 inch”.

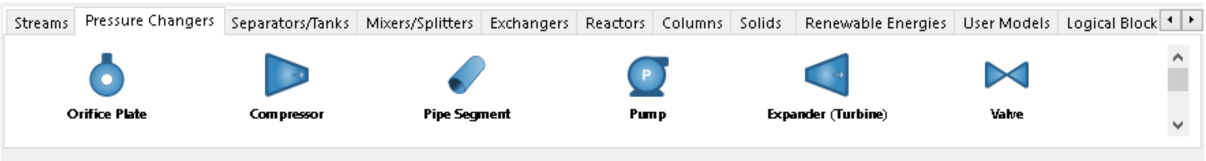

Figure 3 Pipe segment

8. Under specification for pipe segment add the data as follows.

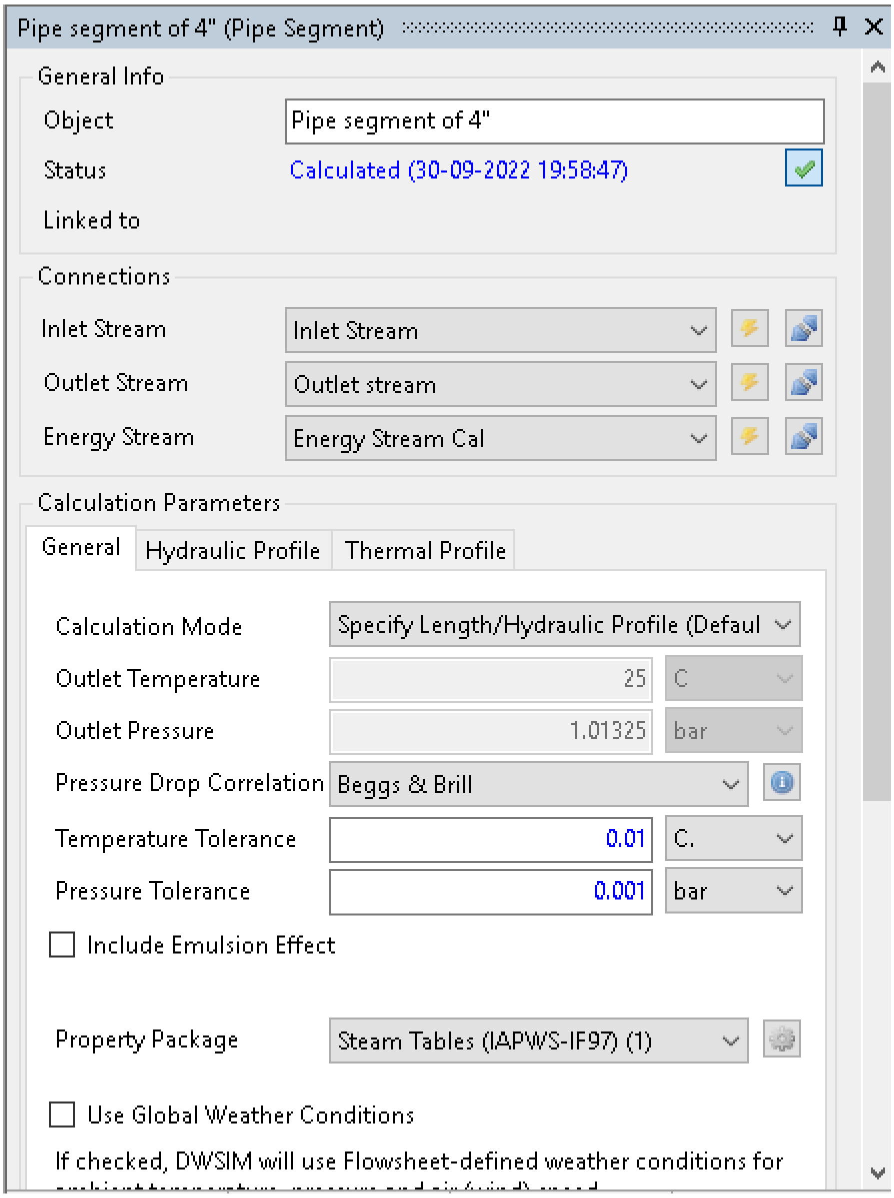

Figure 4 Pie segment Specs

9. Click on the hydraulic profile as shown in the image

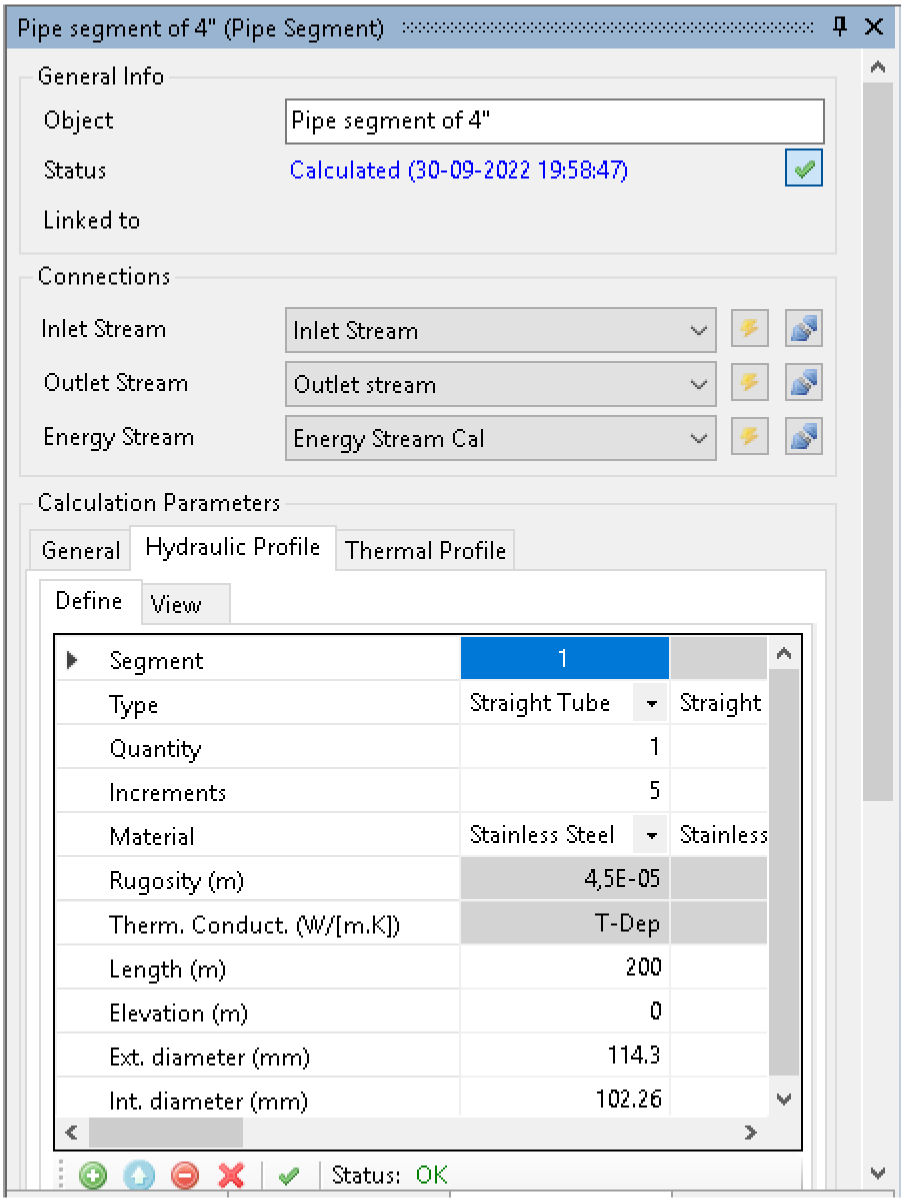

Figure 5 Adding specs for hydraulic profile

Segment	1	2	3	4	5	6
Type	Straight Tube	Straight Tube	Straight Tube	Straight Tube	Straight Tube	Elbow 90 dg [0]
Quantity	1	1	1	1	1	4
Increments	5	5	5	5	5	1
Material	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel
Rugosity (m)	4,5E-05	4,5E-05	4,5E-05	4,5E-05	4,5E-05	4,5E-05

Therm. Conduct. (W/[m.K])	T-Dep	T-Dep	T-Dep	T-Dep	T-Dep	T-Dep
Length (m)	200	5	120	100	150	0.1
Elevation (m)	0	5	0	10	0	0
Ext. diameter (mm)	114.3	114.3	114.3	114.3	114.3	0
Int. diameter (mm)	102.26	102.26	102.26	102.26	102.26	102.26

10. After adding pipe data for segment 1 click on add segment 

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11. Once all segments are added with the data provided as reference in the table above click on green tick mark to apply changes 

12. Click on “View” in hydraulic profile tab to see layout of pipe network

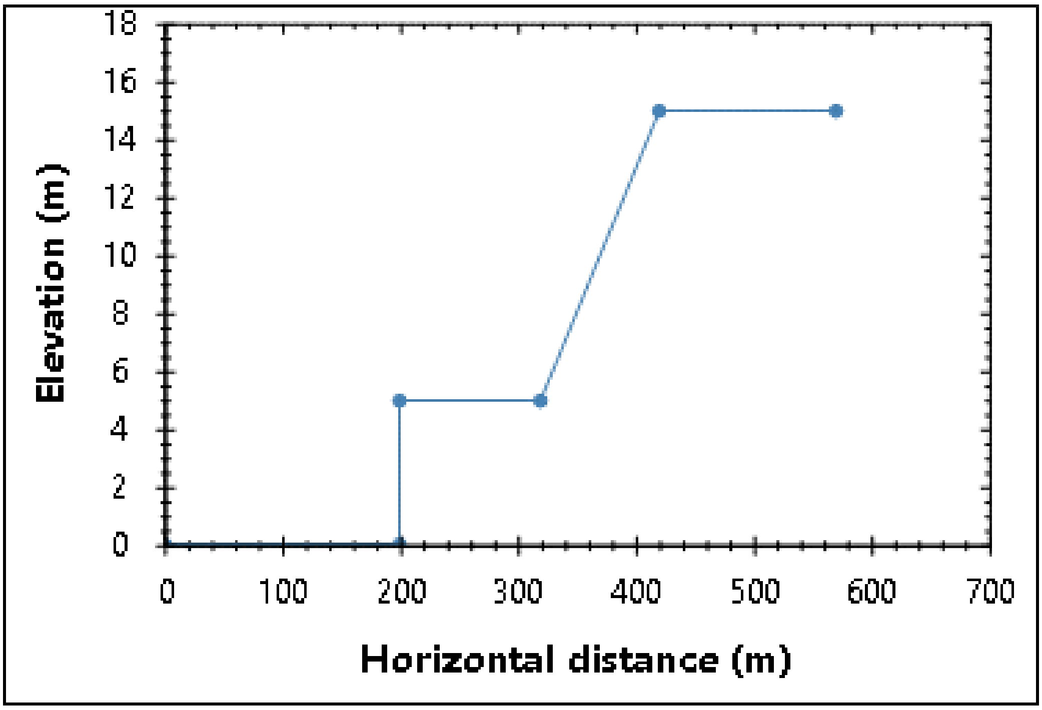

Figure 6 Elevation vs horizontal distance profile

13. Run the simulation by pressing “Solve flow sheet” button on the top corner of the screen.

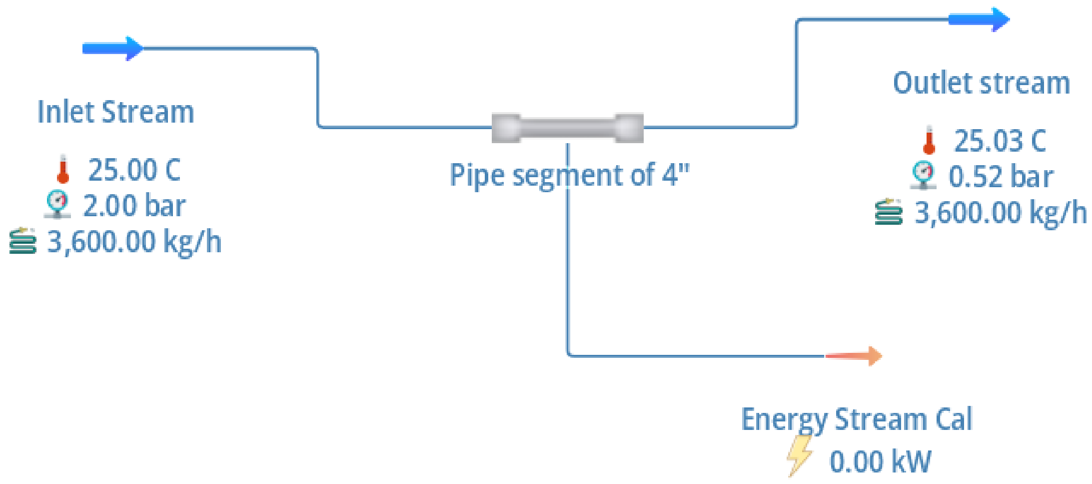

Figure 7 Flow Sheet

	Outlet stream	Inlet Stream
Temperature (C)	25.0436	25
Pressure (bar)	0.0332744	2
Mass Flow (kg/h)	3600	3600
Molar Flow (kmol/h)	199.83	199.83
Volumetric Flow (m3/h)	3.61086	3.6105
Density (Mixture) (kg/m3)	996.993	997.092
Molecular Weight (Mixture) (kg/kmol)	18.0153	18.0153
Specific Enthalpy (Mixture) (kJ/kg)	105.021	105.021
Specific Entropy (Mixture) (kJ/[kg.K])	0.367868	0.367206
Molar Enthalpy (Mixture) (kJ/kmol)	1891.98	1891.98
Molar Entropy (Mixture) (kJ/[kmol.K])	6.62724	6.61531
Thermal Conductivity (Mixture) (W/[m.K])	0.607226	0.60724

3 CROSS-CHECKING IN KORF HYDRAULICS

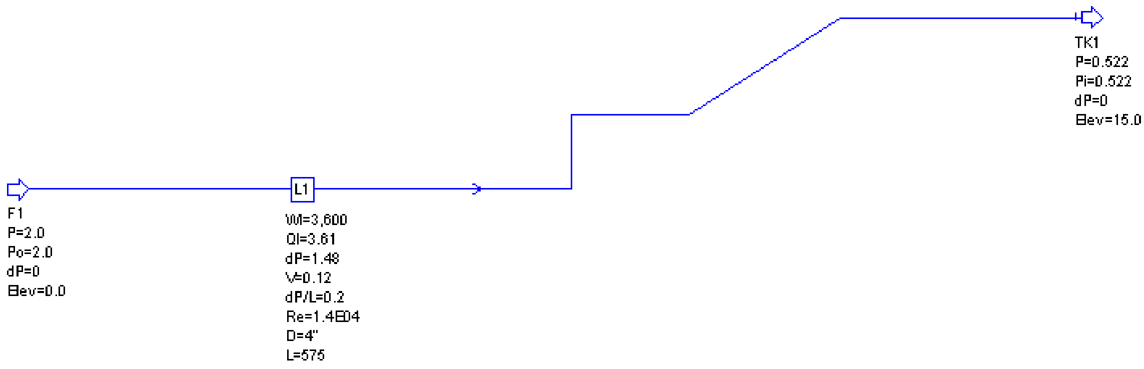

Figure 8 Hydraulic in KORF

Korf Report

4 CROSS CHECKING BY MANUAL CALCULATIONS IN FLUIDS PYTHON MODULE

Problem Statement

Calculate pressure drop for water service to supply 3600 kg/hr pressure of 2 barg and temperature of 25 °C

Consider line length as 575 m

Consider 4 Nos 90 ° elbows

Consider 40 pipe schedule

```
m = 3600*u.kg/u.hr
T = 25*u.degC
P = 2*u.bar + 1*u.atmosphere
L = 575*u.m
dh = 15*u.m
g = g*u.m/u.s**2

Water = Stream('Water', T=T, P=P, m=m)

rho = Water.rho
mu = Water.mu
print('Density = %s' %rho)
print('Viscosity = %s' %mu)
```

```
Density = 997.058312133483 kilogram / meter ** 3
Viscosity = 0.0009125307951858123 pascal * second
```

```
NPS, D_pipe, Do_pipe, t = nearest_pipe(Do=4*u.inch, schedule='40')
Q = m/rho
v = Q/(pi/4*D_pipe**2)
Re = Reynolds(rho=rho, mu=mu, D=D_pipe, V=v)
fd = friction_factor(Re=Re, eD=0.0018*u.inch/D_pipe)
K_elbow = bend_rounded(Di=D_pipe, angle=90*u.degrees, fd=fd)

K_tot = 4*K_elbow
dP = dP_from_K(K=K_tot, rho=rho, V=v) +rho*g*dh
print('Pressure drop = %s' %dP.to(u.bar))
```

```
Pressure drop = 1.4668452605061053 bar
```

Figure 9 Line hydraulics using Fluids Python

[*Line hydraulics using Python Fluids*]

5 GRAPHICAL OUTPUTS IN DWSIM

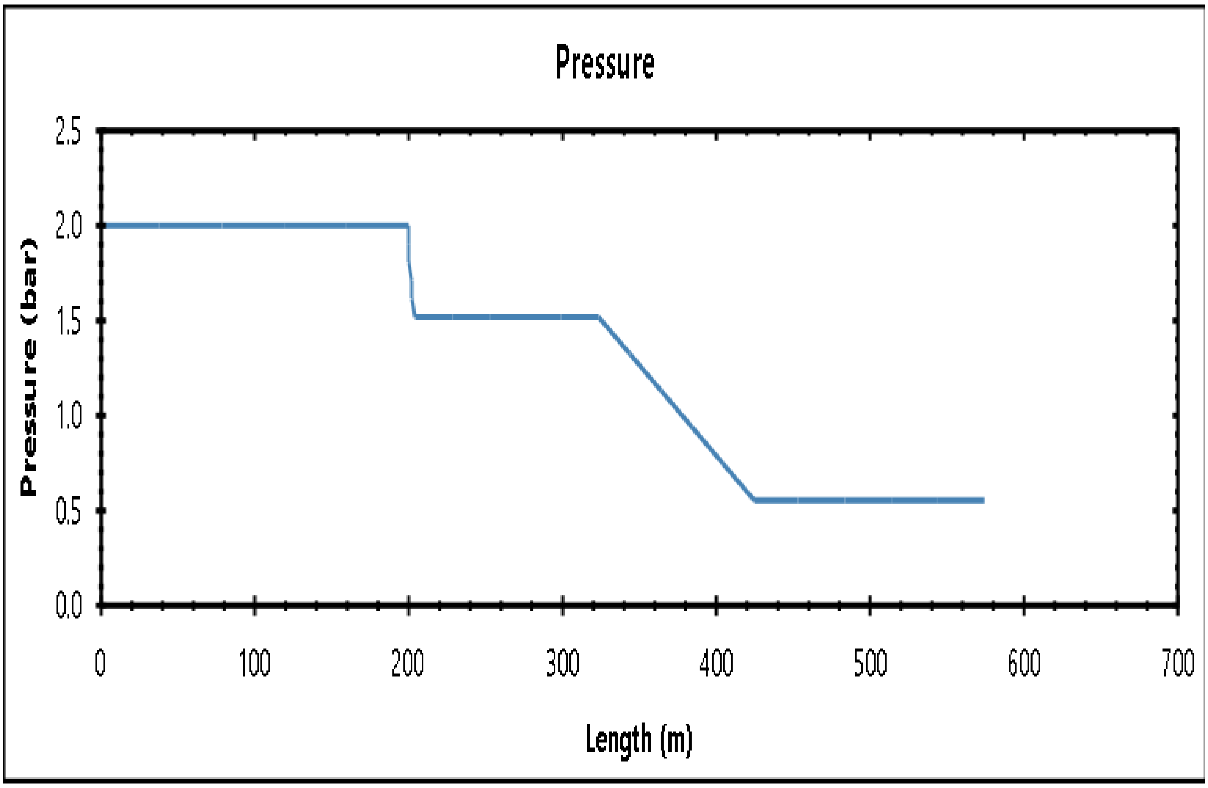

Figure 10 Pressure vs length

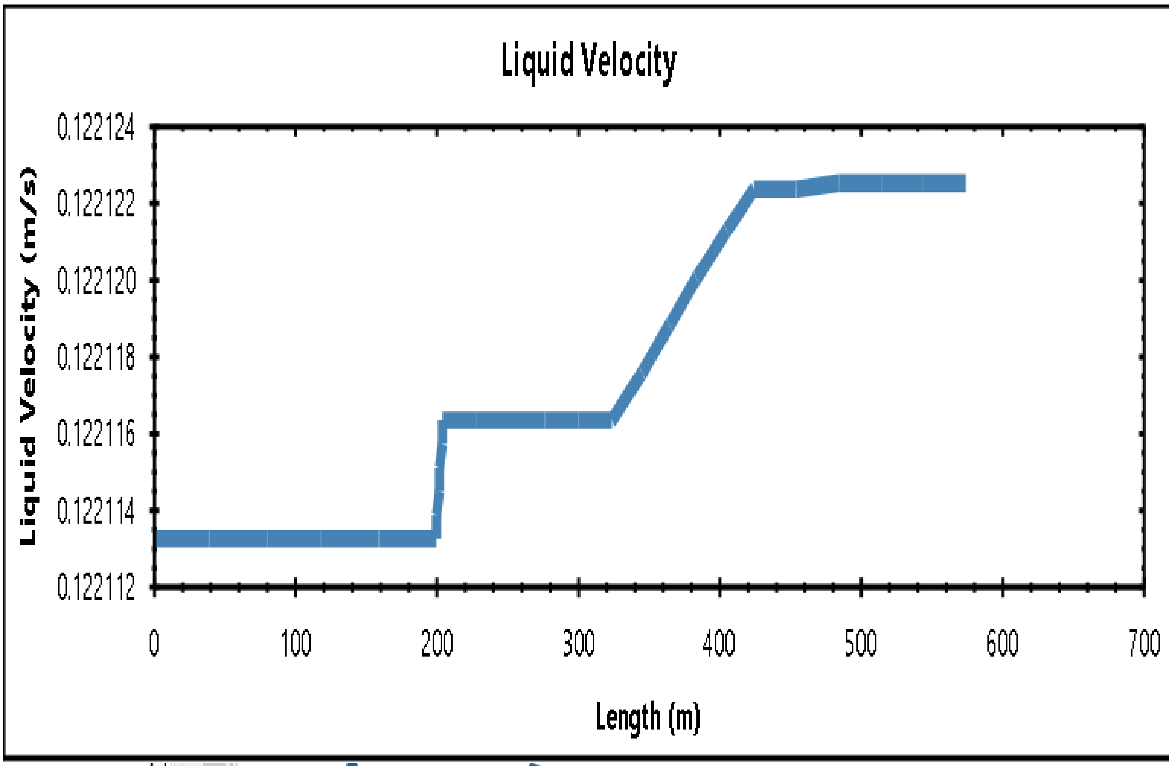

Figure 11 Liquid velocity vs length

Length (m)	Inclination (degrees)	Pressure (bar)	Temperature (C)	Liquid Velocity (m/s)	Vapor Velocity (m/s)	Heat (kW)	Liquid Holdup	Flow Regime	Overall HTC (W/[m2.K])	h (Internal) (W/[m2.K])	k/L (Wall) (W/[m2.K])	k/L (Insulation) (W/[m2.K])	h (External) (W/[m2.K])	External Temperature (C)
0	0	2	25	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
40	0	1.99915	25	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
80	0	1.9983	25	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
120	0	1.99744	25.0001	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
160	0	1.99659	25.0001	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
200	90	1.99574	25.0001	0.122113	0	0	1	Liquid Only	0	0	0	0	0	25
201	90	1.898	25.0023	0.122114	0	0	1	Liquid Only	0	0	0	0	0	25
202	90	1.80027	25.0044	0.122114	0	0	1	Liquid Only	0	0	0	0	0	25
203	90	1.70253	25.0066	0.122115	0	0	1	Liquid Only	0	0	0	0	0	25
204	90	1.6048	25.0088	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
205	0	1.50706	25.0109	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
229	0	1.50655	25.011	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
253	0	1.50604	25.011	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
277	0	1.50553	25.011	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
301	0	1.50502	25.011	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25
325	5.73917	1.50451	25.011	0.122116	0	0	1	Liquid Only	0	0	0	0	0	25

345	5.73917	1.30866	25.0153	0.122118	0	0	1	Liquid Only	0	0	0	0	0	25
365	5.73917	1.11281	25.0197	0.122119	0	0	1	Liquid Only	0	0	0	0	0	25
385	5.73917	0.916958	25.024	0.12212	0	0	1	Liquid Only	0	0	0	0	0	25
405	5.73917	0.721113	25.0284	0.122121	0	0	1	Liquid Only	0	0	0	0	0	25
425	0	0.52527	25.0327	0.122122	0	0	1	Liquid Only	0	0	0	0	0	25
455	0	0.524631	25.0327	0.122122	0	0	1	Liquid Only	0	0	0	0	0	25
485	0	0.523991	25.0327	0.122122	0	0	1	Liquid Only	0	0	0	0	0	25
515	0	0.523352	25.0328	0.122122	0	0	1	Liquid Only	0	0	0	0	0	25
545	0	0.522713	25.0328	0.122122	0	0	1	Liquid Only	0	0	0	0	0	25
575	0	0.522074	25.0328	0.122122	0	0	1	Liquid Only						
575.1	0	0.522009	25.0328	0.122122	0	0	1	Liquid Only						
575.2	0	0.521944	25.0328	0.122122	0	0	1	Liquid Only						
575.3	0	0.521878	25.0328	0.122122	0	0	1	Liquid Only						
575.4	0	0.521813	25.0328	0.122122	0	0	1	-						

6 COMPARISON OF DWSIM, KORF AND FLUIDS PYTHON

Properties	DWSIM	KORF Hydraulics	Fluids Python
Flow sheeting	*Yes*	*Yes*	*No*
Graphs Generation	*Yes*	*No*	*Yes, condition apply if numpy & matplotlib module is used*
Report Generation	*Yes*	*Yes*	*Yes*
Piping Database	*Default gives 6 pipes database, additional can be introduced using user-defined feature*	*Default gives 3 pipes database additional can be introduced using user-defined feature*	*Large piping database*
Fluids Database	*Yes*	*Yes*	*Yes*
User friendly	*Yes*	*Yes*	*Yes, condition apply if you know programming*
UI/UX.	*Yes*	*Yes*	*Yes, condition apply if you know programming*

7 REFERENCES

1. Whiting Crane Handbook
2. Line Hydraulics References
3. Fluids Python