Pump Sizing Using DWSIM:

A Free and Open-Source Chemical Process Simulator

By

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PREFACE

The manual “Pump Sizing Using DWSIM” presents a set of Pump 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
- Line Hydraulics
- Basic Modules

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, pumps, vessels etc.

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

Pump sizing involves matching the flow and pressure rating of a pump with the flowrate and pressure required for the process. The mass flowrate of the system is established on the process flow diagram by the mass balance. Achieving this mass flowrate requires a pump that can generate a pressure high enough to overcome the hydraulic resistance of the system of pipes, valves, and so on that the liquid must travel through. This hydraulic resistance is known as the system head. In other words, the system head is the amount of pressure required to achieve a given flowrate in the system downstream of the pump. The system head is not a fixed quantity — the faster the liquid flows, the higher the system head becomes (for reasons to be discussed later). However, a curve, known as the system curve, can be drawn to show the relationship between flow and hydraulic resistance for a given system. Pump sizing, then, is the specification of the required outlet pressure of a rotodynamic pump (whose output flow varies nonlinearly with pressure) with a given system head (which varies nonlinearly with flow).

Pressure at pump suction is calculated as following

$$\Delta P_{suction} = P_1 + P_{static} - \Delta P_{equipment} + \Delta P_{friction}$$

where, P_1 is pressure at liquid surface in suction vessel, P_{static} is pressure due to height of liquid level above pump suction, $\Delta P_{Equipment}$ is pressure drop in an equipment at pump suction like strainers, filters etc. and $\Delta P_{friction}$ is pressure drop due to suction pipe and fittings.

Pressure at pump discharge is calculated as following

$$\Delta P_{discharge} = P_2 + P_{static} - \Delta P_{equipment} + \Delta P_{friction}$$

where, P2 is pressure at liquid surface in discharge vessel, P_{static} is pressure due to height of liquid level above pump suction, $\Delta P_{Equipment}$ is pressure drop in equipment at pump discharge like heat exchangers, control valve, flowmeter, valves etc and $\Delta P_{friction}$ is pressure drop due to suction pipe and fittings.

Differential head required to be generated by pump is calculated as following.

$$Head = \Delta P_{discharge} - \Delta P_{suction}$$

System Head Curve

System head curve is a graphical representation of the relationship between flow and hydraulic losses in a given piping system. It is prepared by calculating differential head as specified above at different flow. The intersection of the pump manufacturer's curve with system curve defines the operating point of the pump.

Typical Pump Curve

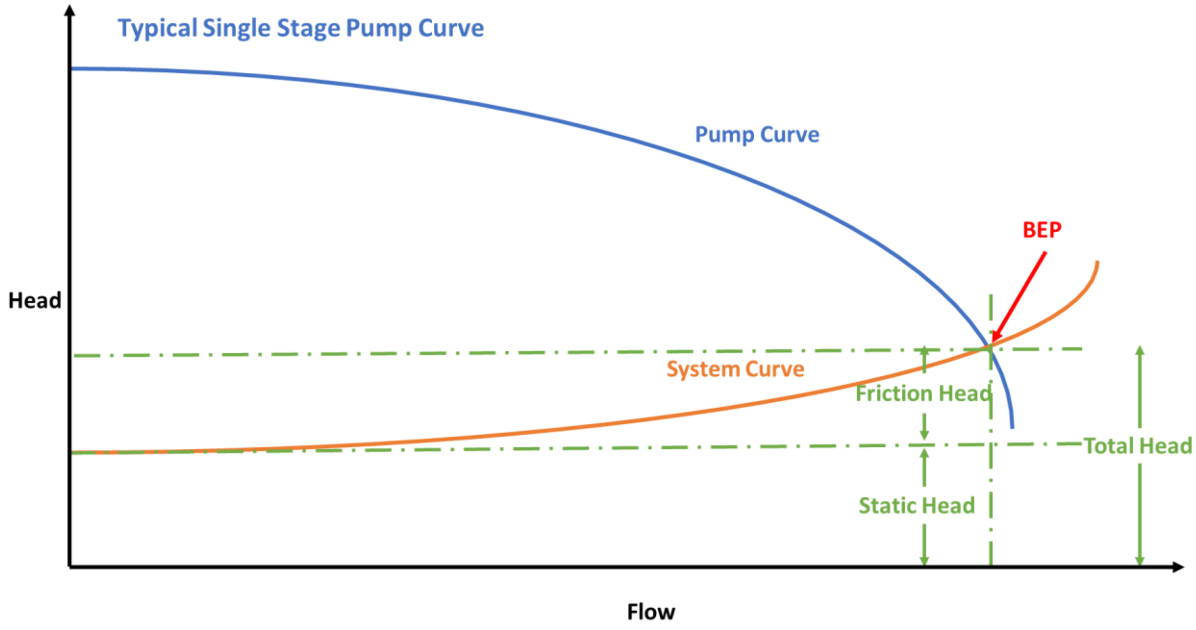

Figure 1 Pump Curve

2 Pump Hydraulics

Objective

Find the Power Requirements, NPSH & Differential pressure

Data

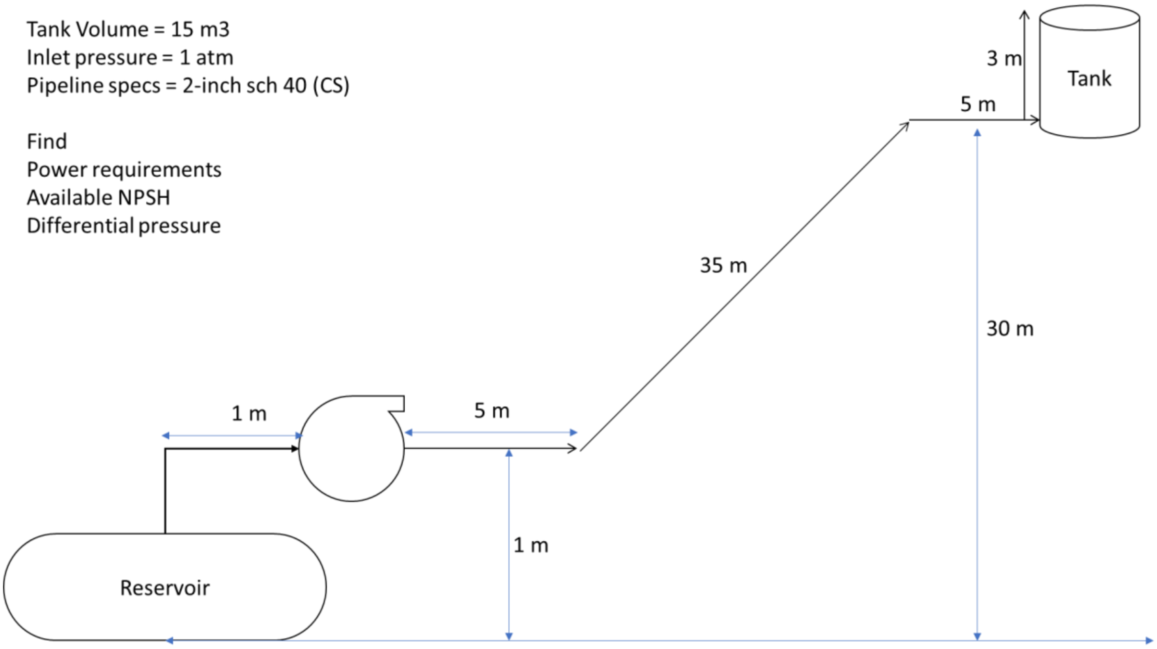

Figure 2 Problem Statement

DWSIM Blocks Used

- Pipe segment
- Material Stream
- Pump
- Tank
- 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 “Reservoir “and “Tank Outlet”.

6. On clicking the “Reservoir” 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.

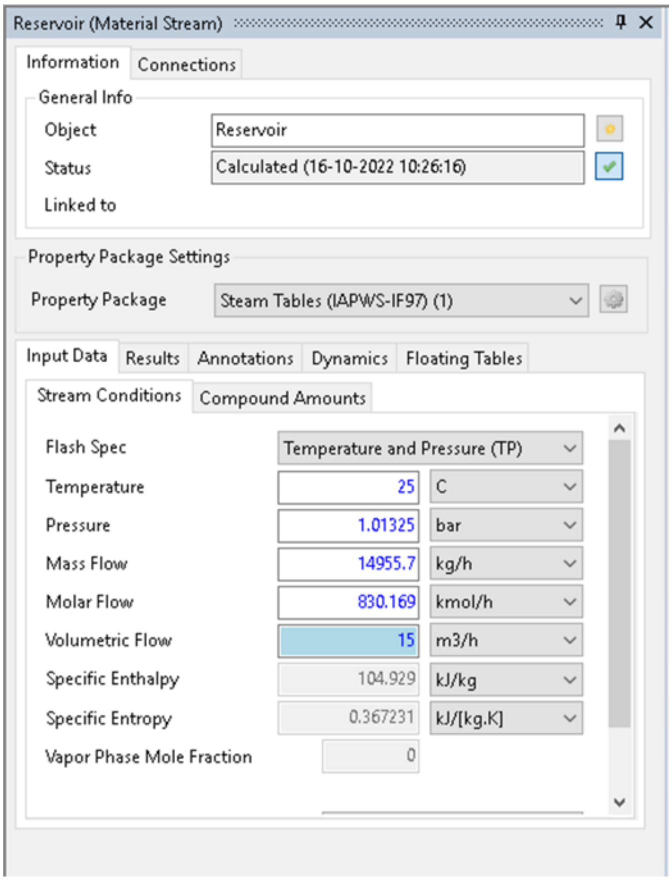

Figure 3 Reservoir stream Specs

7. Below the Unit Operation tab on left, locate the pipe segment block. Drag and drop into the flow sheet. Rename it as “Pipe segment of 2” inlet”.

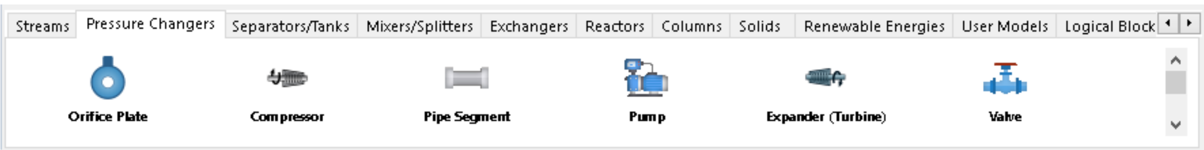

Figure 4 Pipe segment

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

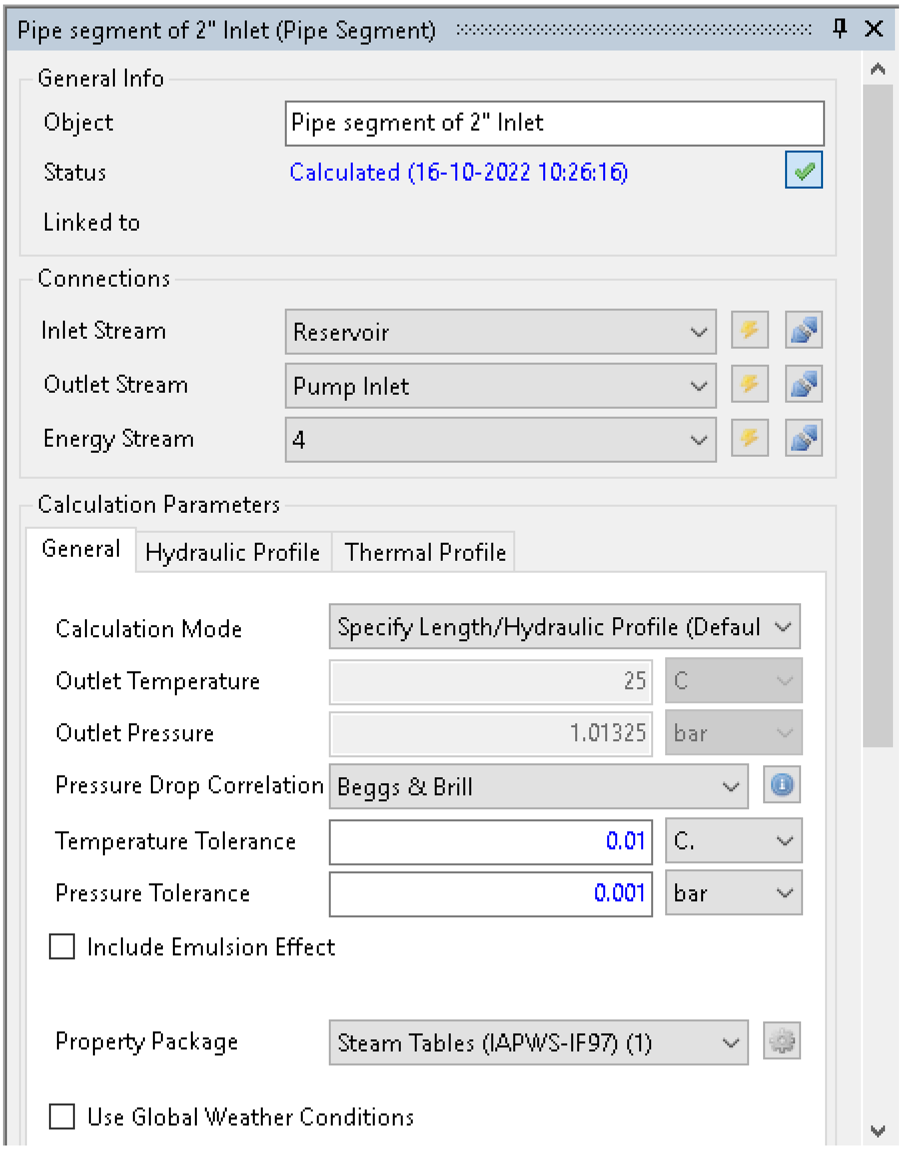

Figure 5 Pipe segment of 2" Inlet Specs

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

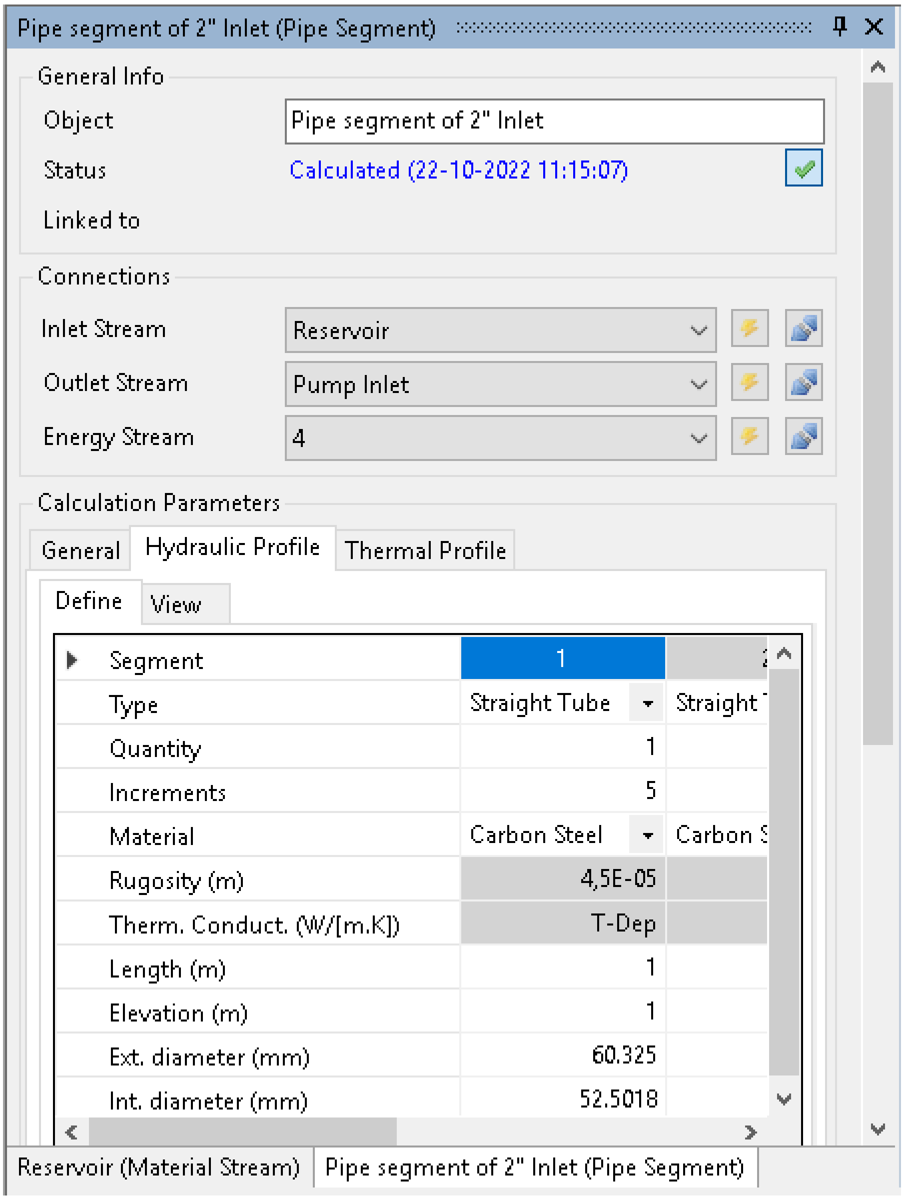

Figure 6 Adding specs for hydraulic profile |Inlet Pipe |

Segment	1	2	3
Type	Straight Tube	Straight Tube	Elbow 90 dg [0]
Quantity	1	1	1
Increments	5	5	1
Material	Carbon Steel	Carbon Steel	Carbon Steel
Rugosity (m)	4,5E-05	4,5E-05	4,5E-05
Therm. Conduct. (W/[m.K])	T-Dep	T-Dep	T-Dep

Length (m)	1	1	0.1
Elevation (m)	1	0	0
Ext. diameter (mm)	60.325	60.325	0
Int. diameter (mm)	52.5018	52.5018	52.5018

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

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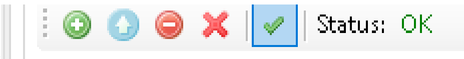
11. Once all segments are added with the data provided as reference in the table above click on green tick mark to apply changes 

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

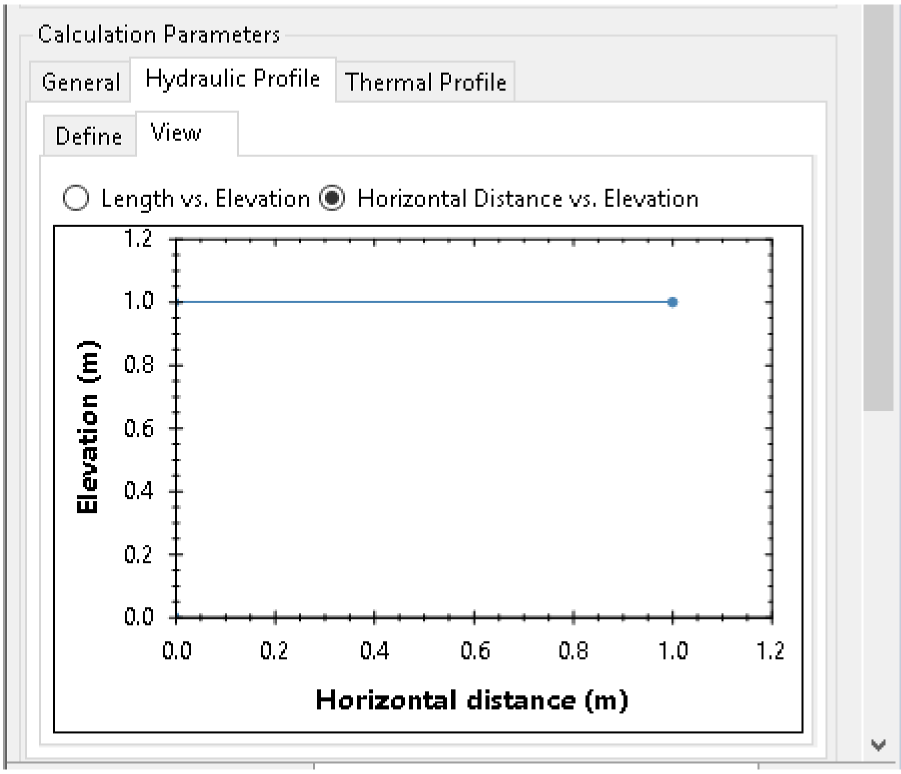


Figure 7 Elevation vs horizontal distance profile for inlet pipe

13. Similarly add a pipe segment name it as "Pipe segment of 2" Outlet" And add the following specs.

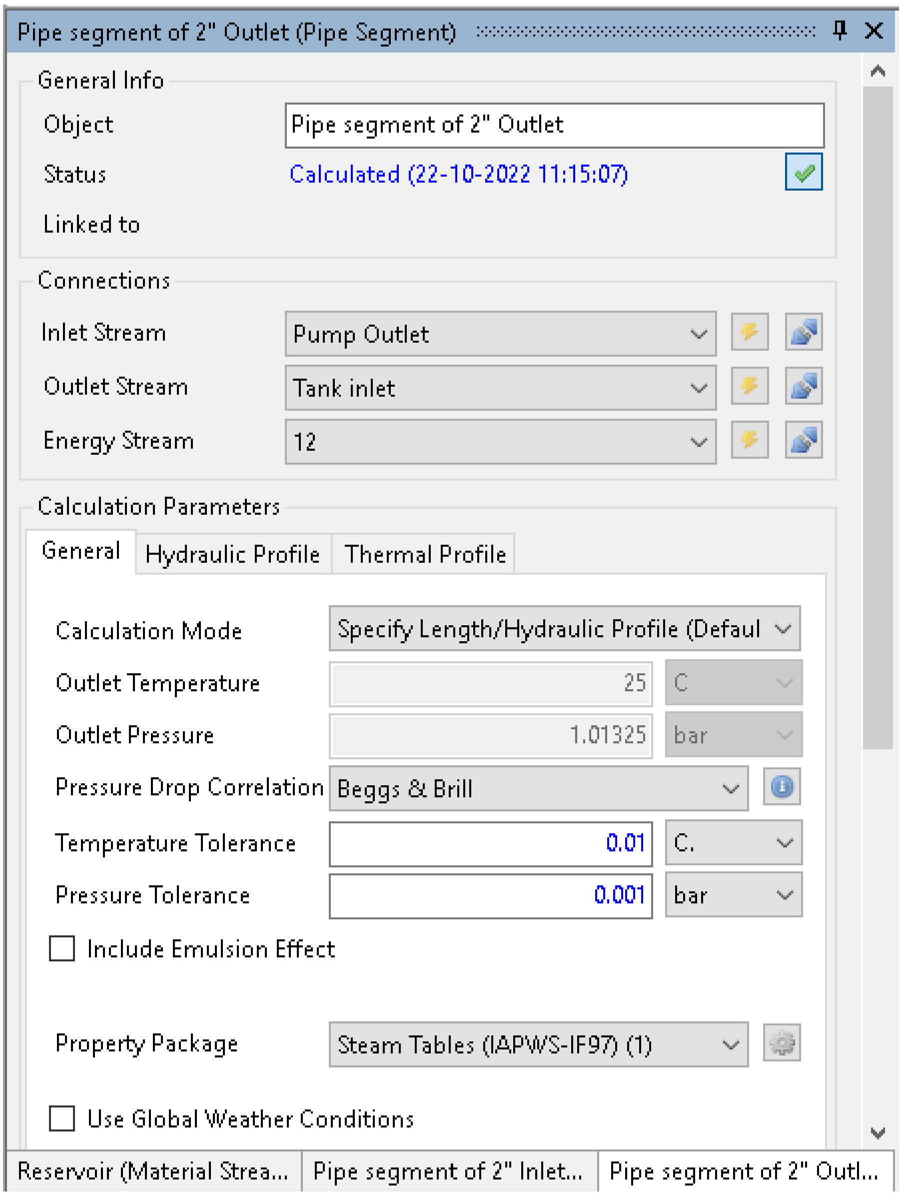


Figure 8 Pipe segment of 2" Outlet Specs

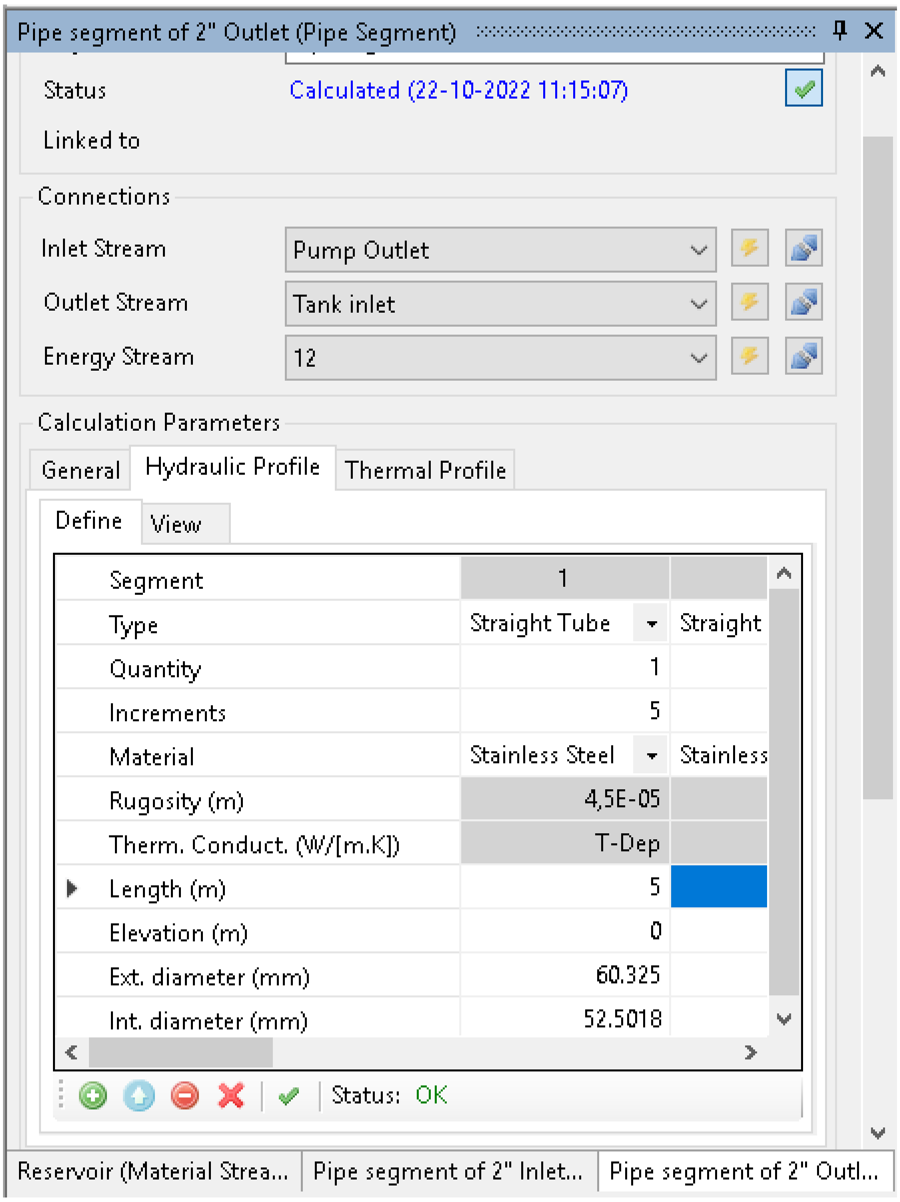


Figure 9 Adding specs for hydraulic profile |Outlet Pipe |

Segment	1	2	3	4	5
Type	Straight Tube	Straight Tube	Straight Tube	Straight Tube	Elbow 90 dg [0]
Quantity	1	1	1	1	4
Increments	5	5	5	5	1
Material	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

Therm. Conduct. (W/[m.K])	T-Dep	T-Dep	T-Dep	T-Dep	T-Dep
Length (m)	5	35	5	3	0.1
Elevation (m)	0	30	0	3	0
Ext. diameter (mm)	60.325	60.325	60.325	60.325	0
Int. diameter (mm)	52.5018	52.5018	52.5018	52.5018	102.26

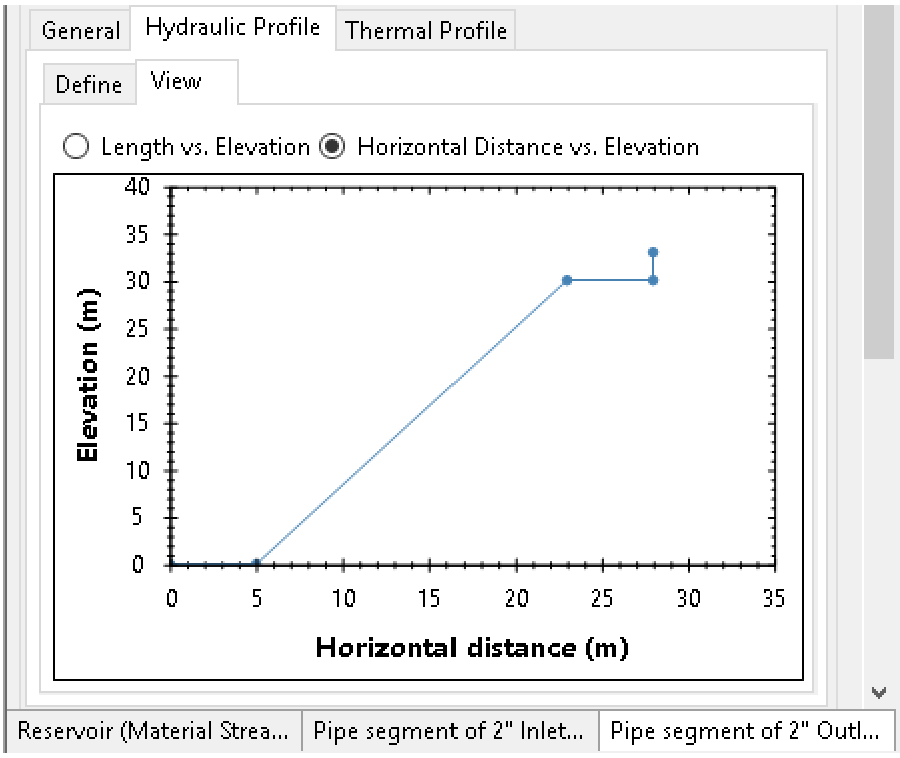


Figure 10 Elevation vs horizontal distance profile for inlet pipe

14. Add a Pump from the pressure changes ribbon and connect the "Pipe segment of 2" inlet" and "Pipe segment of 2" outlet". And add the following specs

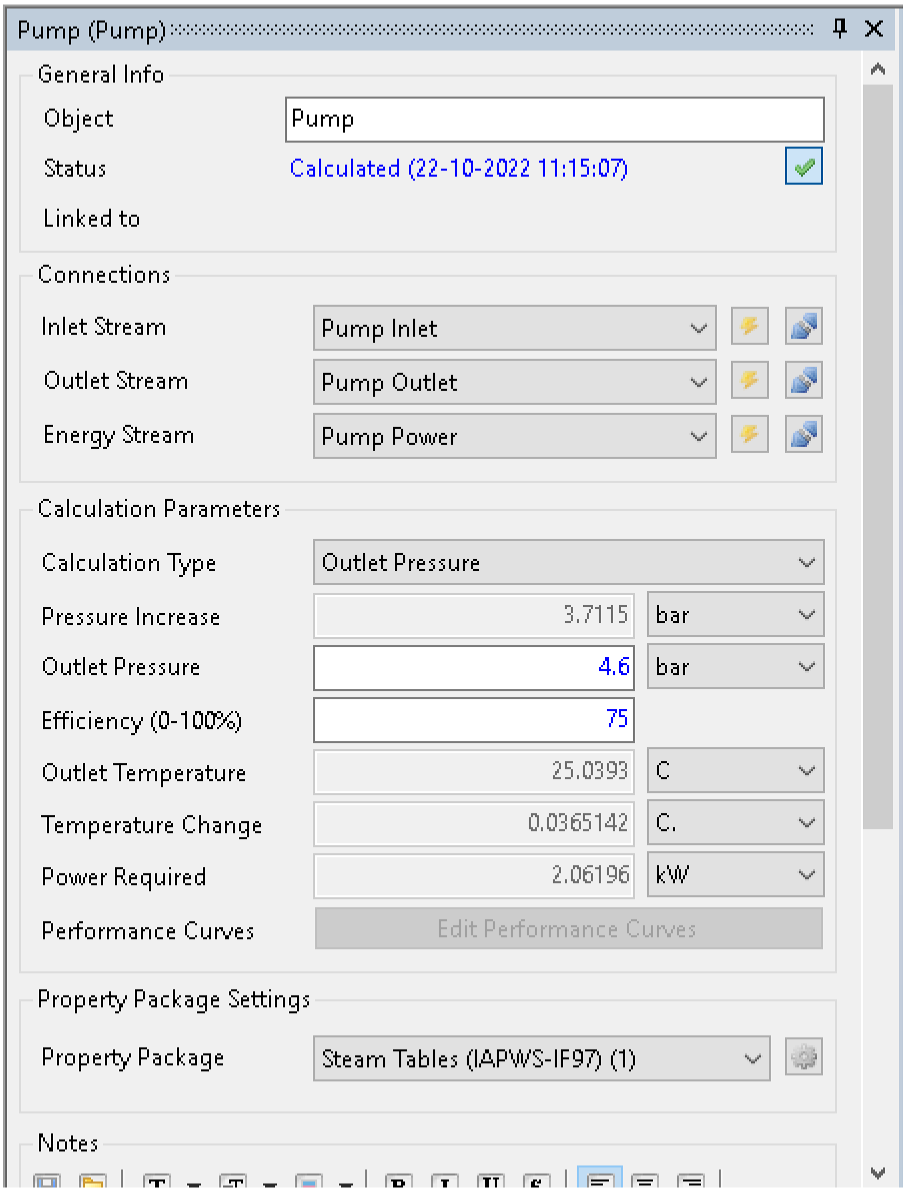


Figure 11 Pump Specs

15. Similarly add a Tank from Separator and tanks ribbon and connect it with “Pipe segment of 2” outlet” and “Tank outlet

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

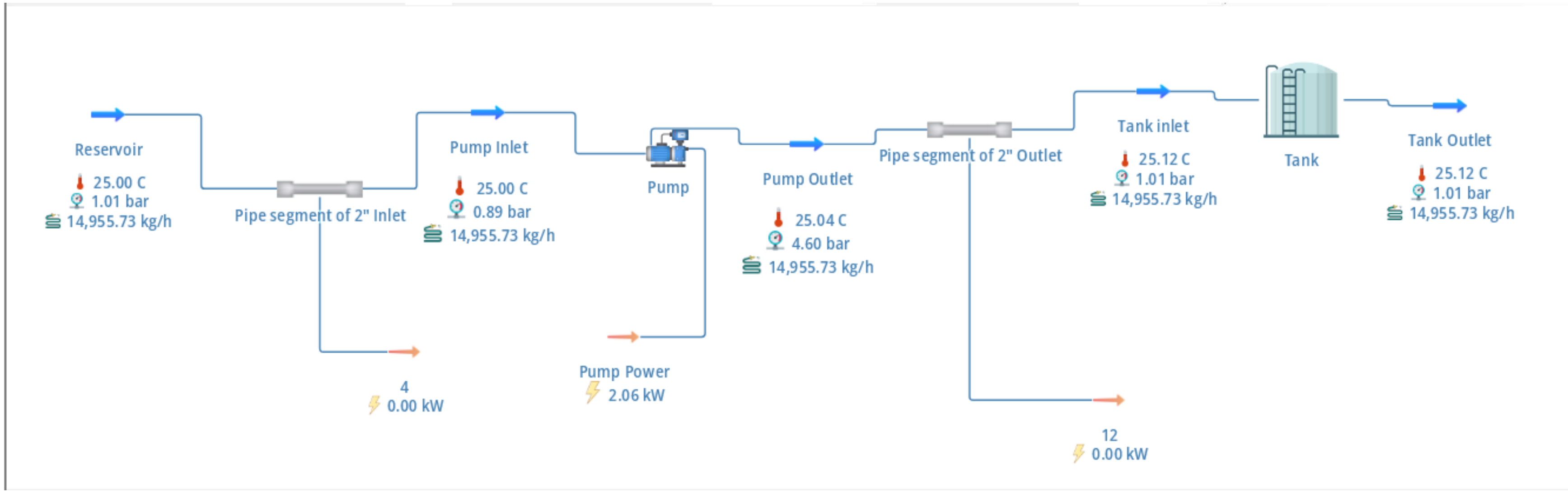


Figure 12 Flow Sheet

17. Click on result tab and generate report for Pump.

Simulation Report

DWSIM 8.2

Details

Title: MySimulation_58

Comments:

Object: Pump

Type: Adiabatic Pump

Property	Value	
Pressure Increase (Head)	3.7115	bar
Efficiency	75	
Temperature Difference	0.0365142	C.
Power Required	2.06196	kW
Available NPSH	8.75983	m
Outlet Pressure	4.6	bar

Figure 13 NPSH

	Tank Outlet	Tank inlet	Pump Outlet	Reservoir	Pump Inlet
Temperature (C)	25.1189	25.1189	25.0393	25	25.0028
Pressure (bar)	1.00897	1.00897	4.6	1.01325	0.888499
Mass Flow (kg/h)	14955.7	14955.7	14955.7	14955.7	14955.7
Molar Flow (kmol/h)	830.169	830.169	830.169	830.169	830.169
Volumetric Flow (m3/h)	15.0005	15.0005	14.9977	15	15.0001
Density (Mixture) (kg/m3)	997.017	997.017	997.199	997.048	997.042
Molecular Weight (Mixture) (kg/kmol)	18.0153	18.0153	18.0153	18.0153	18.0153
Specific Enthalpy (Mixture) (kJ/kg)	105.426	105.426	105.426	104.929	104.929
Specific Entropy (Mixture) (kJ/[kg.K])	0.368898	0.368898	0.36769	0.367231	0.367273
Molar Enthalpy (Mixture) (kJ/kmol)	1899.28	1899.28	1899.27	1890.33	1890.33
Molar Entropy (Mixture) (kJ/[kmol.K])	6.6458	6.6458	6.62403	6.61577	6.61653
Thermal Conductivity (Mixture) (W/[m.K])	0.607398	0.607398	0.607424	0.607195	0.607195

3 Cross-Checking in KORF hydraulics

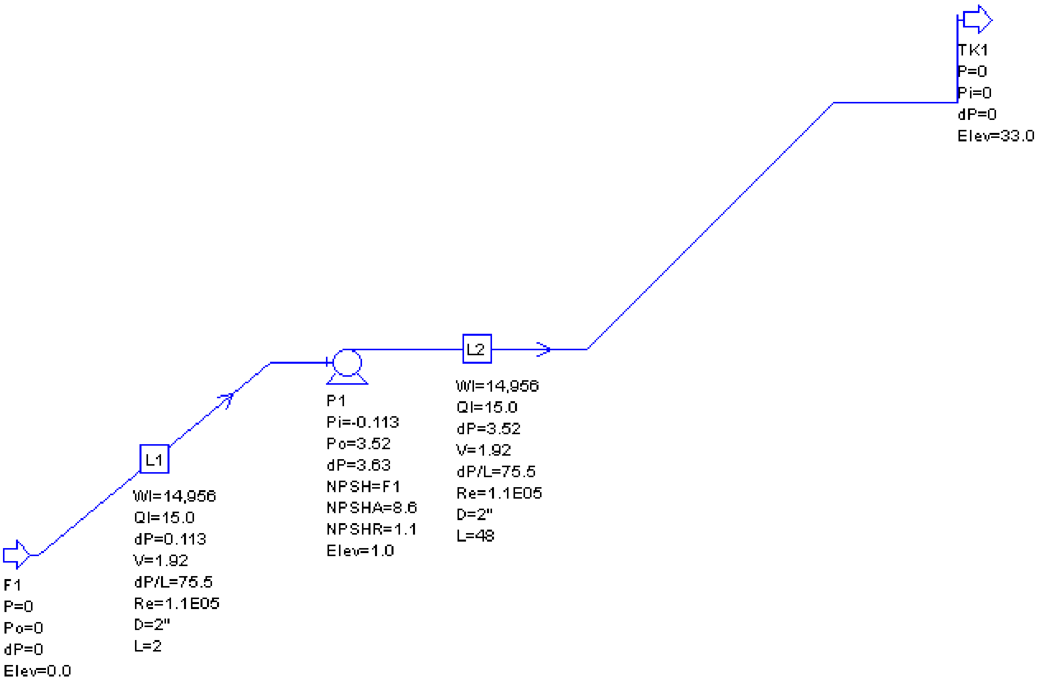


Figure 14 Pump Hydraulic in KORF

[Korf Report]

17 Pump Sizing Korf.pdf

4 GRAPHICAL OUTPUTS IN DWSIM

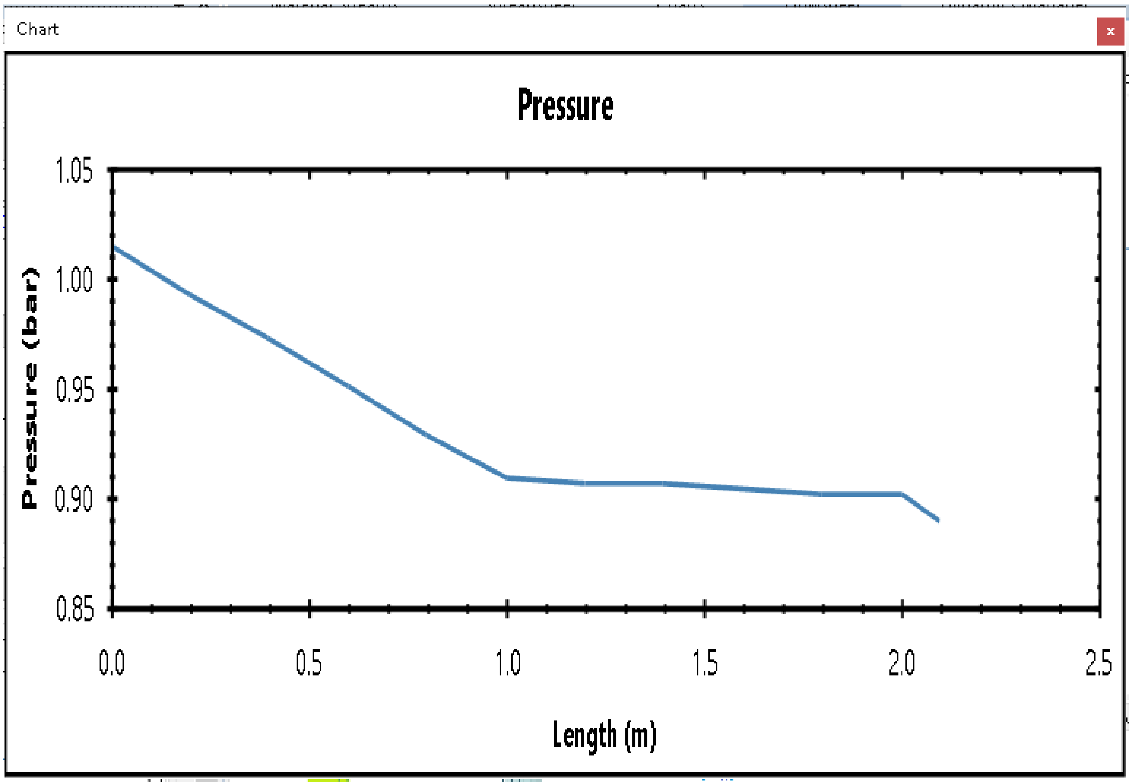


Figure 15 Pressure vs length for inlet pipe

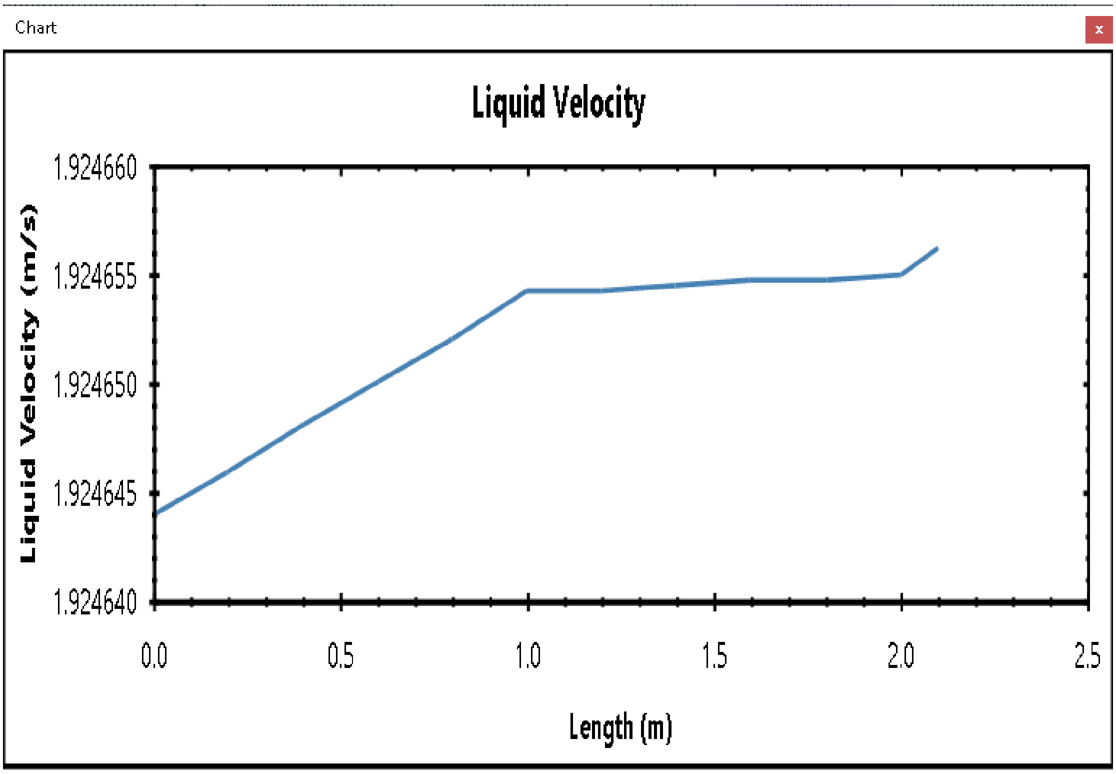


Figure 16 Liquid velocity vs length inlet pipe

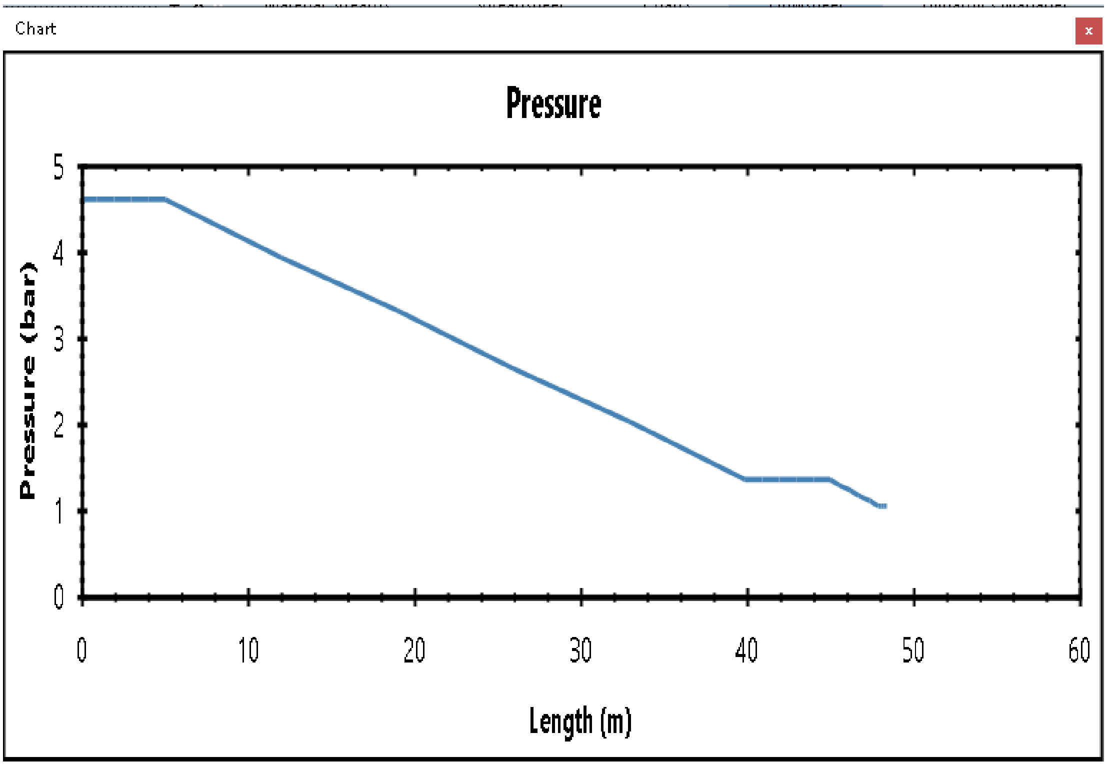


Figure 17 Pressure vs length for outlet pipe

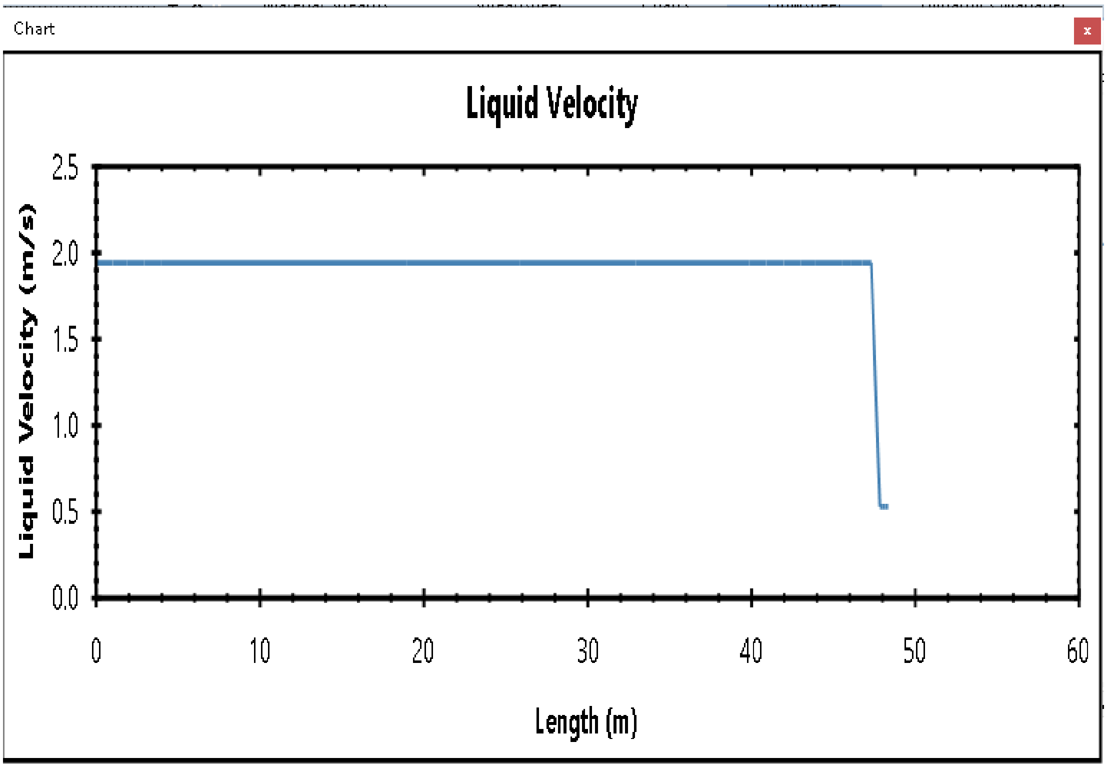


Figure 18 Liquid velocity vs length outlet pipe

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	90	1.01325	25	1.92464	0	0	1	Liquid Only	0	0	0	0	0	25
0.2	90	0.992195	25.0005	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
0.4	90	0.97114	25.0009	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
0.6	90	0.950086	25.0014	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
0.8	90	0.929031	25.0019	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
1	0	0.907976	25.0023	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
1.2	0	0.906463	25.0024	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
1.4	0	0.904951	25.0024	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
1.6	0	0.903438	25.0024	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
1.8	0	0.901925	25.0025	1.92465	0	0	1	Liquid Only	0	0	0	0	0	25
2	0	0.900412	25.0025	1.92465	0	0	1	Liquid Only						
2.1	0	0.888499	25.0028	1.92466	0	0	1	-						
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	4.6	25.0393	1.92435	0	0	1	Liquid Only	0	0	0	0	0	25
1	0	4.59244	25.0395	1.92435	0	0	1	Liquid Only	0	0	0	0	0	25
2	0	4.58488	25.0396	1.92435	0	0	1	Liquid Only	0	0	0	0	0	25

3	0	4.57732	25.0398	1.92435	0	0	1	Liquid Only	0	0	0	0	0	25
4	0	4.56975	25.04	1.92435	0	0	1	Liquid Only	0	0	0	0	0	25
5	58.9973	4.56219	25.0402	1.92436	0	0	1	Liquid Only	0	0	0	0	0	25
12	58.9973	3.92291	25.0543	1.92442	0	0	1	Liquid Only	0	0	0	0	0	25
19	58.9973	3.28364	25.0685	1.92448	0	0	1	Liquid Only	0	0	0	0	0	25
26	58.9973	2.6444	25.0826	1.92454	0	0	1	Liquid Only	0	0	0	0	0	25
33	58.9973	2.00517	25.0968	1.92461	0	0	1	Liquid Only	0	0	0	0	0	25
40	0	1.36596	25.1109	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
41	0	1.3584	25.1111	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
42	0	1.35084	25.1113	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
43	0	1.34328	25.1114	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
44	0	1.33572	25.1116	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
45	90	1.32815	25.1118	1.92467	0	0	1	Liquid Only	0	0	0	0	0	25
45.6	90	1.26499	25.1132	1.92468	0	0	1	Liquid Only	0	0	0	0	0	25
46.2	90	1.20183	25.1146	1.92468	0	0	1	Liquid Only	0	0	0	0	0	25
46.8	90	1.13867	25.116	1.92469	0	0	1	Liquid Only	0	0	0	0	0	25
47.4	90	1.0755	25.1174	1.9247	0	0	1	Liquid Only	0	0	0	0	0	25

48	0	1.01234	25.1188	0.507342	0	0	1	Liquid Only						
48.1	0	1.0115	25.1188	0.507342	0	0	1	Liquid Only						
48.2	0	1.01065	25.1188	0.507342	0	0	1	Liquid Only						
48.3	0	1.00981	25.1188	0.507342	0	0	1	Liquid Only						
48.4	0	1.00897	25.1189	0.507342	0	0	1	-						

5 REFERENCES

1. Whiting Crane Handbook
2. Line Hydraulics References