pipeflow®

taking the pressure out of fluid flow calculations

Liquid Flow Rate

Verification of Calculation Results For Non-Compressible Flow

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Introduction

Pipe Flow Liquid Flow Rate is a software application that calculates the mass flow rate, volumetric flow rate, and resulting fluid velocity that occurs for flow of a liquid in a pipe due to a pressure difference between the start and end of a pipe (the pressure drop). The calculation computes pipe friction losses using the Darcy Weisbach equation with Colebrook-White friction factors. The pressure loss in the pipe is affected by items such as the internal roughness of the pipe material, internal pipe diameter, length of the pipe, fluid flow rate, fluid density, fluid viscosity, and the length of the pipe.

The liquid flow rate calculations produced by the Pipe Flow Liquid Flow Rate software can be verified by comparison against published results from a number of well-known sources. The information in this document provides a general description of a published problem, the **Reference Source**, the **Published Results Data**, the **App Results Data** and a commentary on the results obtained.

For each of the calculation problems detailed in this document, the results data produced by the **Pipe Flow Liquid Flow Rate software compares well with the published results data.**

Calculations

Friction Factors are calculated using the **Colebrook-White** equation.

Friction Loss for non-compressible fluids is calculated using the **Darcy-Weisbach** method, which provides accurate results for Newtonian fluids, including general process fluids.

Software Releases

The Pipe Flow Liquid Flow Rate App is currently available only on iOS (Apple Mobile Devices).

Pipe Flow Software produces a range of different software applications for calculating flow rates and pressure losses in pipe systems, including our premier Pipe Flow Expert software for Windows, which is used to design energy efficient piping and pumping systems.

Pipe Flow Software programs are used by engineers in over 100 countries worldwide.

We have clients in a variety of industries including aerospace, chemical processing, education, food and beverage, general engineering, mining, petrochemical, pharmaceutical, power generation, water distribution, and wastewater processing.

Case 01: Water - Large Diameter Cast Iron Pipe

Reference: 2500 Solved Problems in Fluid Mechanics and Hydraulics, 1989, McGraw-Hill, Jack B. Evett, Ph. D., Cheng Liu, M.S. , Page 209, Example problem 9.64

Liquid Flow Rate App: Find_Flow_Case_01_Water_Large_Diameter_Cast_Iron_Pipe.pfwf

Calculation Problem:

A 96” diameter, new cast iron pipe, has a frictional pressure loss of 1.5 ft. hd per 1000 ft of length, when carrying water at 60°F.

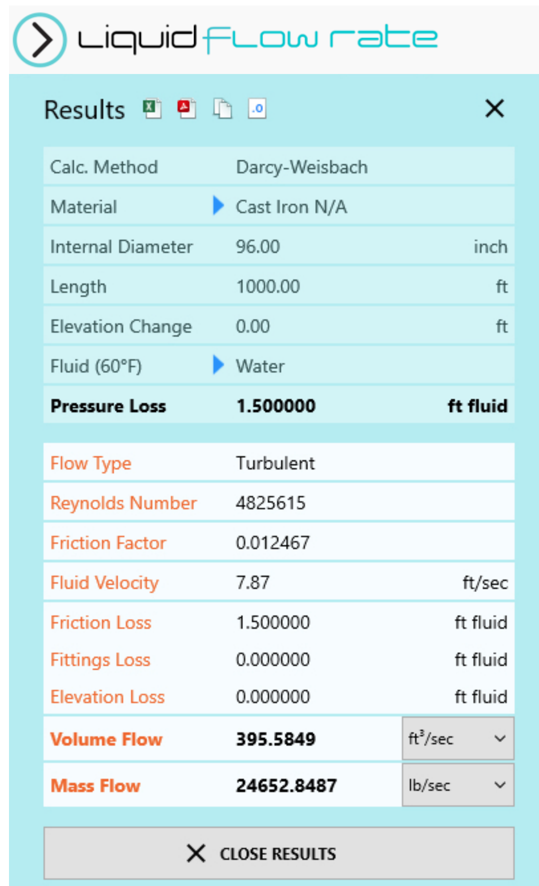
Calculate the discharge capacity of the pipe.

Fluid Data: Water at 60°F (v = 1.21 x 10^{-5} $ft^{2/s}$).

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.



Results Comparison:

Data Item	Published Data	App
Flow Capacity (ft^3/s)	397	395.58
Pressure Loss per 1000 ft. (ft. hd)	1.5	1.5
Friction Factor	0.0124	0.012467

Case 02: Ethanol - Laminar Flow

Reference: 2500 Solved Problems in Fluid Mechanics and Hydraulics, 1989, McGraw-Hill, Jack B. Evett, Ph. D., Cheng Liu, M.S., Page 207, Example problem 9.54

Liquid Flow Rate App: Find_Flow_Case_02_Ethanol_Laminar_Flow.pfwf

Calculation Problem:

Ethanol at 20°C is transferred from an upper tank to a lower tank via a 2 mm pipe.

The upper tank has 0.6 m of fluid above the exit pipe which itself is 1.2 m long, with 0.8 m of this pipe dipping into the fluid in the lower tank.

Calculate the flow rate between the tanks.

Fluid Data: Ethanol at 20°C (μ= 1.20 x 10^{-3} Pa · s)
Density = 788 kg/m^3

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well. The published text does not list an internal roughness for the pipe.

The flow in this problem is laminar, so the friction factor is independent of the inner roughness of the pipe.

The calculated Reynolds number of 883 indicates that the flow type is well within the laminar flow range.

Two pipes with different internal roughness values (0.046000 mm and 0.000001 mm) were used in several Liquid Flow Rate calculations to confirm that the variation in the internal roughness of the pipe did not affect the flow rate calculation.

Results Comparison:

Data Item	Published data	App
Flow from upper tank (l/hr) – Pipe 1	7.59	7.596
Flow from upper tank (l/hr) – Pipe 2	7.59	7.596

Case 03: Water – Flow Between Two Reservoirs

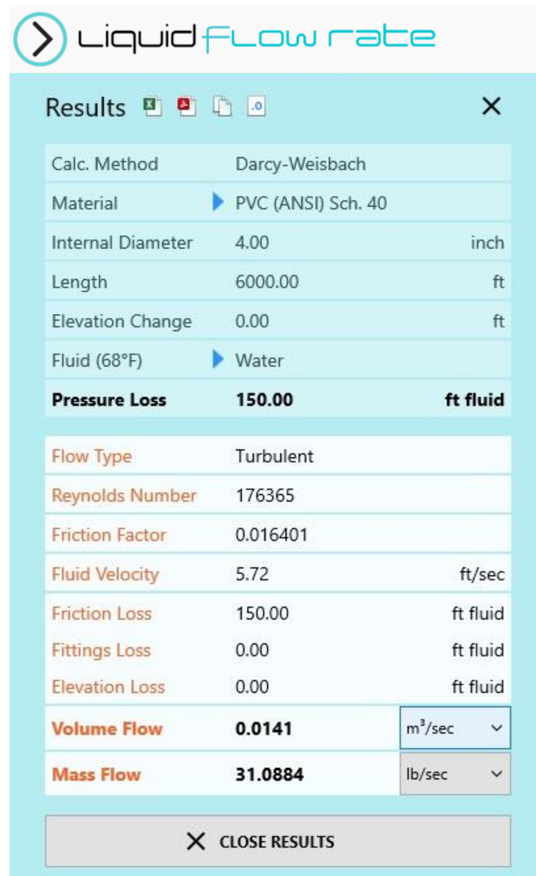
Reference: Analysis of Flow in Pipe Networks, 1976, Roland W. Jeppson Page 35, Example 4

Liquid Flow Rate App: Find_Flow_Case_03_Water_Flow_Between_Two_Reservoirs.pfwf

Calculation Problem:

A 4-inch PVC pipe 6000 ft long is used to convey water at 68°F between two reservoirs whose surface elevations differ by 150 ft.

What is the flow rate?



Fluid Data: Water at 68°F.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published problem obtains the result by first assuming a value for the flow rate and then it uses this to calculate the Reynolds number. The Reynolds number is then used to obtain a value for the friction factor, by reading it from the Moody diagram.

The published solution then iterates the flow rate to achieve the final value which agrees with the head loss specified.

Note: For the published solution, only a small number of iterations are performed, and it is therefore likely that the published Reynolds number and friction factor are not as accurate as those calculated by the Liquid Flow Rate App.

Results Comparison:

Data Item	Published Data	App
Flow Rate (m^3/s)	0.0141	0.014130
Reynolds Number	157000	176365
Friction Factor	0.0165	0.016401

Case 04: Water – Elevated Pipeline with Fittings

Reference: Chemical Engineering, 1999,
J.M. Coulson, J. F. Richardson with J.R. Backhurst, J.H. Harker, Page 92, Example 3.8

Liquid Flow Rate App: Find_Flow_Case_04_Water_Elevated_Pipeline_With_Fittings.pfwf

Calculation Problem:

Water in a tank flows through an outlet 25 m below the water level into a 0.15 m diameter horizontal pipe (e/d = 0.01), 30 m long, with a 90° elbow which leads to a horizontal pipe of the same diameter, 60 m long, containing a fully open globe valve and discharging to atmosphere 10 m below the level of the water in the tank.

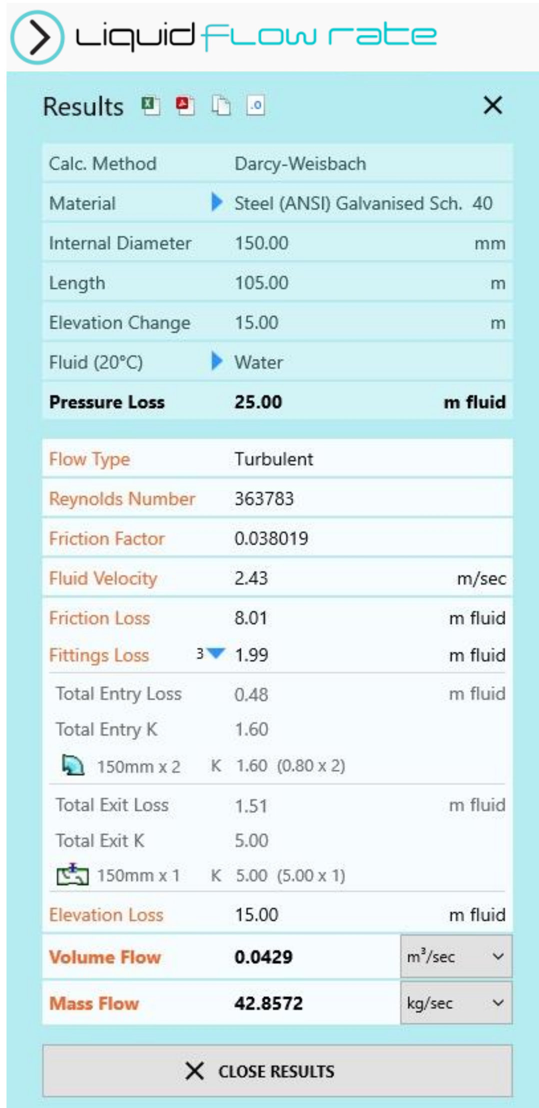
What is the initial rate of discharge?

Fluid Data: Water with viscosity of 1mN s/m^2.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.



Results Comparison:

Data Item	Published Data	App
Flow Rate (m^3/s)	0.043	0.042943
Velocity (m/s)	2.45	2.430079
Reynolds Number	367000	363783
Friction θ $\left(\phi = \frac{f}{2} = \frac{f'}{8}\right)$	0.0045	0.004752 derived from ($\frac{f'}{8} = \frac{0.038019}{8}$)

Note: *f* = fanning friction factor, *f'* = Moody chart friction factor (as shown by the App)

Case 05: Water – Flow Through Reduced Port Ball Valve

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Page 4-3, Example 4-6

Liquid Flow Rate App: Find_Flow_Case_05_Water_Flow_Through_Reduced_Port_Ball_Valve.pfwf

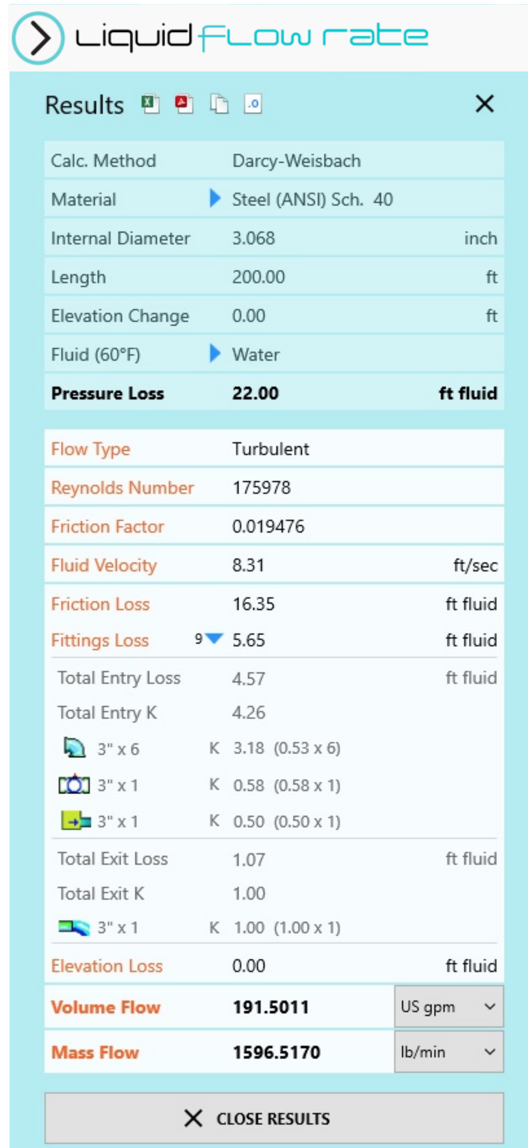
Calculation Problem:

200 ft of 3" diameter steel pipe (schedule 40) carries water at 60°F.

The head of fluid in the supply tank is 22 ft.

The piping includes 6 standard 90° elbows and a flanged ball valve with a conical seat.

Find the fluid velocity in the pipe and the rate of discharge.



Fluid Data: Water at 60°F

Commentary:

See the Results Comparison Table below.

The published data and the calculated results differ by 2.3%.

The published data uses an assumed friction factor of 0.018 for a 3" diameter steel pipe.

As a final check, in the published data, the friction factor is read from a chart as less than 0.02, and the text concludes that the difference in the assumed friction factor and the friction factor read from the chart, is small enough so as not to require any further correction.

If the chart is read accurately the real friction factor is 0.0195. The App calculated a friction factor of 0.019476

A new valve fitting was created in Liquid Flow Rate to model the flanged ball valve as this item is not included in the database of standard valves and fittings.

Results Comparison:

Data Item	Published Data	App
Fluid Velocity in Pipe (ft/s)	8.5	8.311
Rate of Discharge (gpm US)	196	191.50
Reynolds Number	Not calculated	175978
Friction Factor	0.018 (assumed)	0.019476

Case 06: SAE 10 Lube Oil - Laminar Flow in Valves

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Page 4-4, Example 4-7

Liquid Flow Rate App: Find_Flow_Case_06_SAE_10_Lube_Oil_Laminar_Flow_In_Valves.pfwf

Calculation Problem:

200 feet of 3" diameter steel pipe (schedule 40) carries SAE 10 Lube Oil at 60°F.

The head of fluid in the supply tank is 22 ft.
The piping includes 6 standard 90° elbows and a flanged ball valve with a conical seat.

Find the fluid velocity in the pipe and the rate of discharge.

Fluid Data: SAE 10 Lube Oil at 60°F

Commentary:

See the Results Comparison Table below.

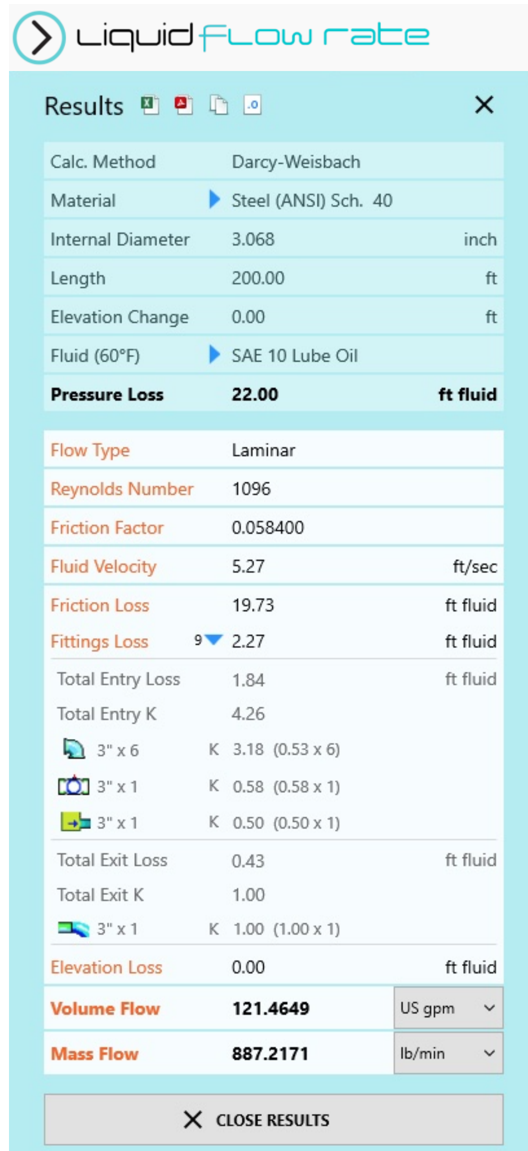
The published data and the calculated results differ by 3%.

The published text acknowledges that the problem has two unknowns and requires a trial and error solution.

The published data results are for the initial assumed velocity. The published result is therefore likely to be slightly inaccurate.

The App performs numerous iterations to find a solution which is accurate to within 0.0004 ft head of pressure loss.

A new valve fitting was created in Liquid Flow Rate to model the flanged ball valve as this item is not included in the database of standard valves and fittings.



Results Comparison:

Data Item	Published Data	App
Fluid Velocity in Pipe (ft/s)	5.13	5.27
Rate of Discharge (gpm US)	118	121.46
Reynolds Number	1040 (1st Iteration)	1096
Friction Factor	0.062 (1st Iteration)	0.05840

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