



# سأصاب



Verification of Calculation Results For Non-Compressible Flow

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## Introduction



**Pipe Flow Liquid Pressure Drop** is a software application that calculates the pressure drop for liquids in a pipe due to pipe friction losses using the Darcy Weisbach equation with Colebrook-White friction factors. The pressure drop in the pipe is affected by items such as the internal roughness of the pipe material,

internal pipe diameter, length of pipe, fluid flow rate, fluid density, fluid viscosity, and the length of pipe used.

The liquid pressure loss calculations produced by the Pipe Flow Liquid Pressure Drop 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 Pressure Drop 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 Pressure Drop 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: Petroleum - Oil Pipeline Pressure Loss

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, P.E., Page 335, Example 6.16

Liquid Pressure Drop App: Find\_Pressure\_Case\_01\_Petroleum\_Oil\_Pipeline\_Pressure\_Loss.pfwp

#### **Calculation Problem:**

Find the head loss in one mile of NPS16 pipeline (0.250 inch wall thickness) at a flow rate of 4000 barrel/h.

#### Fluid Data:

Petroleum oil with 0.85 specific gravity and 10 cSt viscosity.

#### Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published data rounds the fluid velocity to 2 decimal places and the friction factor to 4 decimal places.

The App uses a velocity and a friction factor that are calculated to more decimal places, which accounts for the slight differences in calculated head loss.

Results 🖭 🖻 🖟	2	×
Calc. Method	Darcy-Weisbach	
Material 💦 🔻	Stainless Steel (ANSI	)
Schedule / Class	Sch. 40S	
Internal Roughness	0.002	inch
Nominal Size	16	inch
Internal Diameter	15.5	inch
Length	5280	ft
Elevation Change	0	ft
Fluid	Oil	
Temperature	68	۴
Density	53.063766	lb/ft <sup>3</sup>
Viscosity	10	Centistokes
Volume Flow	4000	Brls/hr
Mass Flow	1191723.74475	lb/hour
Flow Type	Turbulent	
Reynolds Number	57130	
Friction Factor	0.020784	
Fluid Velocity	4.760847	ft/sec
Friction Loss	29.926491	ft fluid
Fittings Loss	0.000000	ft fluid
Elevation Loss	0.000000	ft fluid
Pressure Drop	29.926491	ft fluid 🗸 🗸

Data Item	Published Data	Арр
Head Loss (ft. hd)	29.908	29.9265
Reynolds Number	57129	57130
Fluid Velocity (ft/s)	4.76	4.7608
Friction Factor	0.0208	0.020784

# Case 02: Gasoline - Transport over 15 km

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, P.E., Page 337, Example 6.17

Liquid Pressure Drop App: Find\_Pressure\_Case\_02\_Gasoline\_Transport\_Over\_15km.pfwp

#### **Calculation Problem:**

A DN500 (10mm wall thickness) steel pipe, with an internal roughness of 0.05 mm, is used to transport gasoline over a 15 km distance. The delivery point is 200 m above the start of the pipeline. A delivery pressure of 4 kPa must be maintained at the delivery point.

Calculate the pump pressure needed to deliver a flow rate of 990 m<sup>3</sup>/h.

#### Fluid Data:

Gasoline Specific Gravity = 0.736 Viscosity = 0.6 Centistokes (0.4416 Centipoise)

#### Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well. The published text uses a friction factor value of 0.013 read from the Moody diagram.

The App uses a friction factor calculated to more decimal places which accounts for the slight difference in the pump pressure required.

Results 🖪 🖻 🛙	È	×
Calc. Method	Darcy-Weisbach	
Material 💦	Steel (ANSI)	
Schedule / Class	Sch. 40	
Internal Roughness	0.05	mm
Nominal Size	500	mm
Internal Diameter	480	mm
Length	15000	m
Elevation Change	200.000000	m
Fluid	Gasoline	
Temperature	20	°C
Density	736.000000	kg/m <sup>3</sup>
Viscosity	0.441600	Centipoise
Volume Flow	990	m³/hour
Mass Flow	728640	kg/hour
Flow Type	Turbulent	
Reynolds Number	1215767	
Friction Factor	0.013289	
Fluid Velocity	1.519709	m/sec
Friction Loss	352.953724	kPa
Fittings Loss	0.000000	kPa
Elevation Loss	1443.538880	kPa
Pressure Drop	1796.492604	kPa 🗸

Data Item	Published Data	Арр
Pump Pressure Required (kPa)	1792	1796.49
Reynolds Number	1215768	1215767
Fluid Velocity (m/s)	Not stated	1.52
Friction Factor	0.013	0.013289

# Case 03: SAE 10 Oil - Pressure Loss per Mile

**Reference:** 2500 Solved Problems in Fluid Mechanics and Hydraulics 1989, McGraw-Hill, Jack B. Evett, Ph. D., Cheng Liu, M.S., Page 211, Example problem 9.68

Liquid Pressure Drop App: Find\_Pressure\_Case\_03\_SAE\_10\_Oil\_Pressure\_Loss\_Per\_Mile.pfwp

#### **Calculation Problem:**

A 6" wrought iron pipe carries SAE 10 oil at 68°F.

Calculate the pressure loss per mile of pipe.

#### Fluid Data:

SAE 10 at 68°F.

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

The App calculates the friction factor to a greater number of decimal places.

Results 🖭 🖺	à	×
Calc. Method	Darcy-Weisbach	
Material	Wrought Iron N/A	
Internal Diameter	6	inch
Length	5280	ft
Elevation Change	0	ft
Fluid (68°F)	SAE 10 Oil	
Volume Flow	2	ft³/sec
Mass Flow	49.169413	kg/sec
Flow Type	Turbulent	
Reynolds Number	5047	
Friction Factor	0.037657	
Fluid Velocity	10.185916	ft/sec
Friction Loss	241.331554	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	241.331554	psi 🗸

Data Item	Published Data	Арр
Pressure Loss per mile. (psi)	244	241.33
Reynolds Number	5035	5047
Friction Factor	0.038	0.037657

# Case 04: Water - Asbestos Cement Pipe Friction Loss

**Reference:** Basic Principles for the Design of Centrifugal Pump Installations SIHI Group, 1998, SIHI-HALBERG. Page 134, Example of Head Loss Calculation

Liquid Pressure Drop App: Find\_Pressure\_Case\_04\_Water\_Asbestos\_Cement\_Pipe\_Friction\_Loss.pfwp

#### **Calculation Problem:**

Water flows along a 400 m long asbestos cement pipe at the rate of 360 m $^{3}$ /h.

The pipe designation is DN200.

Find the head loss in the pipe.

#### Fluid Data:

Water at 10°C.

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results 🖭 😫	Ē.	×
Calc. Method	Darcy-Weisbach	i I
Material	Asbestos Cemer	nt Pipe Class A
Internal Diameter	200	mm
Length	400	m
Elevation Change	0	m
Fluid (10°C)	Water	
Volume Flow	<b>7</b> 360	m³/hour
Mass Flow	100	kg/sec
Flow Type	Turbulent	
Reynolds Number	487458	
Friction Factor	0.015897	
Fluid Velocity	3.183099	m/sec
Friction Loss	16.424593	m fluid
Fittings Loss	0.000000	m fluid
Elevation Loss	0.000000	m fluid
Pressure Drop	16.424593	m fluid 🗸 🗸

Data Item	Published Data	Арр
Reynolds Number	4.9 x 10⁵	487458
Fluid Velocity (m/s)	3.2	3.18
Total Head Loss in pipe (m. hd)	16.4	16.42

# Case 05: Lubrication Oil - Laminar Flow Example 1

Reference: Flow of Fluids - Technical Paper No 410M, 1999, Crane Co. Page 3-12, Example 1

Liquid Pressure Drop App: Find\_Pressure\_Case\_05\_Lubricating\_Oil\_Laminar\_Flow\_Example\_1.pfwp

#### **Calculation Problem:**

A 6" diameter schedule 40 steel pipe carries lubricating oil of density 897 kg/m<sup>3</sup> and viscosity 450 Centipoise.

Find the pressure drop per 100 meters.

#### Fluid Data:

Lubricating Oil Viscosity = 450 Centipoise, Density = 897 kg/m<sup>3</sup>

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results 🖭 🖻 🖟	2	×
Calc. Method	Darcy-Weisbach	
Material 💦	Steel (ANSI)	
Schedule / Class	Sch. 40	
Internal Roughness	0.001811	inch
Nominal Size	6	inch
Internal Diameter	6.065	inch
Length	100	m
Elevation Change	0	m
Fluid	Lubricating Oil	
Temperature	20	°C
Density	897	kg/m <sup>3</sup>
Viscosity	450	Centipoise
Volume Flow 🛛 🤜	3000	l/min
Mass Flow	44.85	kg/sec
Flow Type	Laminar	
Reynolds Number	824	
Friction Factor	0.077693	
Fluid Velocity	2.682570	m/sec
Friction Loss	1.627738	bar
Fittings Loss	0.000000	bar
Elevation Loss	0.000000	bar
Pressure Drop	1.627738	bar 🗸

Data Item	Published Data	Арр
Pressure Drop per 100 meters (bar)	1.63	1.628
Reynolds Number	825	824

## Case 06: Lubrication Oil - Laminar Flow Example 2

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Page 3-12, Example 2

Liquid Pressure Drop App: Find\_Pressure\_Case\_06\_Lubricating\_Oil\_Laminar\_Flow\_Example\_2.pfwp

#### **Calculation Problem:**

A 3" diameter schedule 40 carries SAE 10 lube oil at a velocity of 5.0 ft/s

Find the flow rate and the pressure drop per 100 feet.

#### Fluid Data:

Oil, viscosity = 95 Centipoise, density = 54.64 lb/ft<sup>3</sup>

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results 🖭 🖭	6	×
Calc. Method	Darcy-Weisbach	
Material	Steel (ANSI) Sch. 40	)
Internal Diameter	3.068	inch
Length	100	ft
Elevation Change	0	m
Fluid (20°C)	Oil	
Volume Flow	<b>7</b> 115	US gpm
Mass Flow	6.348397	kg/sec
Flow Type	Laminar	
Reynolds Number	1092	
Friction Factor	0.058616	
Fluid Velocity	4.990875	ft/sec
Friction Loss	3.366535	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	3.366535	psi 🗸

Data Item	Published Data	Арр
Flow Rate (US gpm)	115	115
Fluid Velocity (ft/s)	5.00	4.99
Reynolds Number	1100	1092
Pressure Drop per 100 feet (psi)	3.40	3.367

# Case 07: Water - Reynolds Number for Smooth Wall Pipe

Reference: Flow of Fluids - Technical Paper No 410, 1988, Crane Co. Page 4-1, Example 4-1

Liquid Pressure Drop App: Find\_Pressure\_Case\_07\_Water\_Reynolds\_Number\_For\_Smooth\_Wall\_Pipe.pfwp

#### **Calculation Problem:**

70 feet of 2" diameter plastic pipe (smooth wall) carries water at 80°F. The flow rate is 50 gpm (US).

Find the Reynolds number and the friction factor.

#### Fluid Data:

Water at 80°F

#### Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The App uses the same fluid density and viscosity as the published text to calculate the Reynolds number.

The published text friction factor has been read from a chart for water at 60°F.

Results 🖭 🖭	D.	×
Calc. Method	Darcy-Weisbach	
Material	PVC (ANSI) Sch. 40	
Internal Diameter	2.067000	inch
Length	70	ft
Elevation Change	0.000000	ft
Fluid (80°F)	Water	
Volume Flow	50.000000	US gpm
Mass Flow	415.880208	lb/min
Flow Type	Turbulent	
Reynolds Number	89702	
Friction Factor	0.018883	
Fluid Velocity	4.780559	ft/sec
Friction Loss	2.725380	ft fluid
Fittings Loss	0.000000	ft flui <mark>d</mark>
Elevation Loss	0.000000	ft fluid
Pressure Drop	2.725380	ft fluid 🗸

Data Item	Published Data	Арр
Reynolds Number	89600	89702
Friction Factor	0.0182	0.018883

# Case 08: SAE 70 Lube Oil - Laminar Flow in Valves

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Page 4-4, Example 4-8

Liquid Pressure Drop App: Find\_Pressure\_Case\_08\_SAE\_70\_Lube\_Oil\_Laminar\_Flow\_In\_Valves.pfwp

#### **Calculation Problem:**

200 feet of 8" diameter steel pipe (schedule 40) carries SAE 70 Lube Oil at 100°F.

The flow rate is 600 barrels per hour.

The piping includes an 8" globe valve.

Find the pressure loss in the pipe and the valve.

#### Fluid Data:

SAE 70 Lube Oil at 100°F

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results 🖭 🖻 🛛	<u>à</u>	×
Calc. Method	Darcy-Weisbach	
Material	Steel (ANSI)	
Schedule / Class	Sch. 40	
Internal Roughness	0.001811	inch
Nominal Size	8	inch
Internal Diameter	7.9810	inch
Length	200.00	f
Elevation Change	0.00	f
Fluid	SAE 70 Lube Oil	
Temperature	100.0	٩
Density	56.1000	lb/ft
Viscosity	470.0000	Centipoise
Volume Flow	600.0001	Brls/h
Mass Flow	188986.8974	lb/hour
Flow Type	Laminar	
Reynolds Number	318	
Friction Factor	0.201124	
Fluid Velocity	2.69	ft/sec
Friction Loss	6.819157	ft fluid
Fittings Loss 1	0.541195	ft fluid
Total Entry Loss	0.541195	ft fluid
Total Entry K	4.80	
🔄 8" x 1 🛛 I	< 4.80 (4.80 x 1)	
Elevation Loss	0.00	ft fluic

Data Item	Published Data	Арр
Pressure Loss (psi)	2.85	2.8675
Reynolds Number	318	318
Friction Factor	0.20	0.201124

# Case 09: Water and Oil – Uncoated Cast Iron Pipe

**Reference:** Fluid Mechanics and Hydraulics – Third Edition 1994 Ranald V. Giles, Jack B. Evett, Ph.D., Cheng Liu, Page 149, Example problem 8.15

Liquid Pressure Drop App: Find\_Pressure\_Case\_09\_Water\_Oil\_Cast\_Iron\_Pipe.pfwp

#### **Calculation Problem:**

1000 ft of new uncoated 12" internal diameter cast iron pipe carries:

- (a) Water 60°F at 5.00 ft/sec, and
- (b) Medium fuel oil 60°F at the same velocity.

Determine the pressure loss (head loss) in the pipe.

#### Fluid Data:

- (a) Water at 60°F Kinematic Viscosity = 1.217 x 10<sup>-5</sup> ft<sup>2</sup>/sec.
- (b) Medium Fuel Oil at 60°F Kinematic Viscosity= 0.858 ft<sup>2</sup>/sec.

#### **Commentary:**

See the Results Comparison Table below.

The published data and the calculated results compare well.

The Example used a relative roughness of 0.0008, and this value was also used in the Liquid Pressure Drop calculation.

The Friction factor in the published data was read from Diagram A-1, given in Appendix A (page 346).

The App used the Colebrook- White equation to calculate the accurate friction factor.

Results 🖭 🖺	Đ	×
Calc. Method	Darcy-Weisbach	
Material	Cast Iron Class A	
Internal Diameter	12.000000	inch
Length	1000.000000	ft
Elevation Change	0.000000	ft
Fluid	<ul> <li>Medium Fuel Oil</li> </ul>	
Temperature	60.000000	°F
Density	53.563190	lb/ft <sup>3</sup>
Viscosity	3.786140	Centipoise
Volume Flow	3.926991	ft <sup>3</sup> /sec
Mass Flow	210.342162	lb/sec
Flow Type	Turbulent	
Reynolds Number	105267	
Friction Factor	0.021356	
Fluid Velocity	5.000000	ft/sec
	8.297014	ft fluid
Friction Loss	0.000000	ft fluid
Friction Loss Fittings Loss	0.000000	
Friction Loss Fittings Loss Elevation Loss	0.000000	ft fluid

Data Item	Published Data	Арр	Published Data	Арр
Fluid	Water	Water	Medium Fuel Oil	Medium Fuel Oil
Pressure Loss (ft head)	7.5	7.552	8.3	8.297
Reynolds Number	411000	410868	105000	105267
Friction Factor	0.0194	0.019438	0.0213	0.021356

# Case 10: Water – Pressure Loss due to Friction

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, P.E., Page 16, Example 1.9

Liquid Pressure Drop App: Find\_Pressure\_Case\_10\_Water\_Pressure\_Loss.pfwp

#### **Calculation Problem:**

Water flows through a 16 inch pipeline (0.375 inch wall thickness) at 3000 gal/min. Assume a pipe roughness of 0.002 inches.

Calculate the friction factor and head loss due to friction in 1000 ft of pipe length.

#### Fluid Data:

Water Kinematic Viscosity of 1.0 cSt

#### **Commentary:**

See the Results Comparison Table below.

The problem does not give the temperature of water however it specifies a kinematic viscosity of 1.0 cSt.

The Liquid Pressure Drop calculation used water at 20°C which has a kinematic viscosity 0f 1.004008 cSt.

The problem description did not specify a pipe material. The App used Steel Schedule 40 with a pipe roughness of 0.002 inches.

The published data and the calculated results compare well.

Results 🖭 🖺	6	×
Calc. Method	Darcy-Weisbach	
Material	Steel (ANSI) Sch. 40	
Internal Diameter	15.25	inch
Length	1000	ft
Elevation Change	0	m
Fluid (20°C)	Water	
Volume Flow	▼ 3000	US gpm
Mass Flow	188.892049	kg/sec
Flow Type	Turbulent	
Reynolds Number	619659	
Friction Factor	0.014442	
Fluid Velocity	5.269521	ft/sec
Friction Loss	2.121780	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	2.121780	psi 🗸

Data Item	Published Data	Арр
Pressure Drop due to Friction (psi)	2.12	2.122
Reynolds Number	622131	619659
Friction Factor	0.0144	0.014442

# Case 11: Oil – Laminar Flow in Pipeline

Reference: Analysis of Flow in Pipe Networks, 1976, Roland W. Jeppson Page 32, Examples 1 and 2

Liquid Pressure Drop App: Find\_Pressure\_Case\_11\_Oil\_Laminar\_Flow.pfwp

#### **Calculation Problem:**

A flow rate of 150 gpm ( $0.00947 \text{ m}^3/\text{s}$ ) of oil occurs in a 4-inch (0.1016 m) pipe line.

Determine the Reynolds number and head loss per 1000ft (304.8m).

#### Fluid Data:

#### Oil

Viscosity	$\mu = 1.5 \text{ x } 10^{-3} \text{ lb-sec/ft}^2 (0.0718 \text{ N} \cdot \text{sec/m}^2)$
Density	$\rho$ = 1.7 slug/ft <sup>3</sup> (876 kg/m <sup>3</sup> ).

#### **Commentary:**

See the Results Comparison Table below.

The problem does not specify the pipe material data. We used Steel Schedule 40 with an internal roughness of 0.001811.

The published data and the calculated results compare well.

Results 🖭 🖭	6	×
Calc. Method	Darcy-Weisbach	
Material	Steel (ANSI) Sch.	40
Internal Diameter	4	inch
Length	1000	ft
Elevation Change	0	m
Fluid (40°C)	Oil	
Volume Flow	<b>v</b> 150	US gpm
Mass Flow	8.290052	kg/sec
Flow Type	Laminar	
Reynolds Number	1447	
Friction Factor	0.044231	
Fluid Velocity	3.829666	ft/sec
Friction Loss	30.243919	ft fluid
Fittings Loss	0.000000	ft fluid
Elevation Loss	0.000000	ft fluid
Pressure Drop	30.243919	ft fluid 🗸

Data Item	Published Data	Арр
Pressure Loss (ft head)	30.2	30.244
Reynolds Number	1450	1447

# Case 12: Oil – Head loss in Cast Iron Pipeline

Reference: Fluid Mechanics and Hydraulics – Third Edition, 1994, Ranald V. Giles, Jack B. Evett, Ph.D., Cheng Liu, Page 149, Example problem 8.11

Liquid Pressure Drop App: Find\_Pressure\_Case\_12\_Oil\_Head\_Loss\_Cast\_Iron\_Pipeline.pfwp

#### **Calculation Problem:**

Oil Flows through 3000 m of 300 mm cast iron pipe at the rate of 0.0444 m<sup>3</sup>/s.

#### What is the lost head in the pipe?

#### Fluid Data:

Oil Absolute Viscosity Specific Gravity

= 0.101 N⋅s/m<sup>2</sup> = 0.850.

#### Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results 🖲 😫	D.	×
Calc. Method	Darcy-Weisbach	
Material	Cast Iron Class A	
Internal Diameter	300	mm
Length	3000	m
Elevation Change	0	m
Fluid (40°C)	Oil	
Volume Flow	<b>0.044</b> 4	m³/sec
Mass Flow	37.74	kg/sec
Flow Type	Laminar	
Reynolds Number	1586	
Friction Factor	0.040356	
Fluid Velocity	0.628132	m/sec
Friction Loss	8.118225	m fluid
Fittings Loss	0.000000	m fluid
Elevation Loss	0.000000	m fluid
Pressure Drop	8.118225	m fluid 🗸

Data Item	Published Data	Арр
Pressure Loss (m head)	8.14	8.118
Reynolds Number	1582	1586
Friction Factor	0.0405	0.040356

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