



www.pipeflow.com

Pipe Flow Wizard

Software for Fluid Flow and Pressure Loss Calculations

Gases

Verification of Calculation Results For Compressible Isothermal Flow

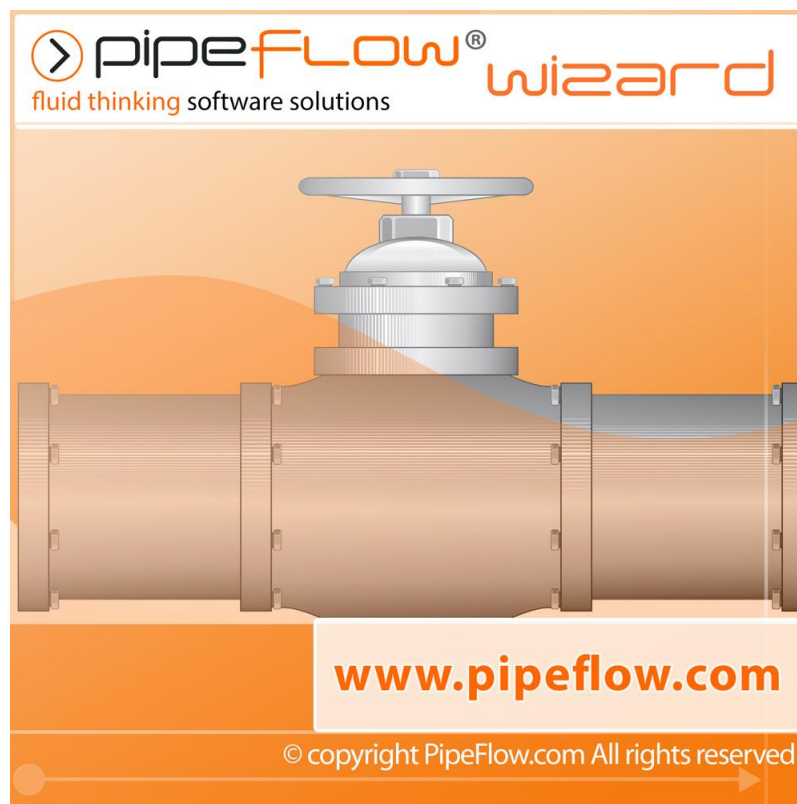


Table of Contents – Results Data: Systems Solved by Pipe Flow Wizard

Introduction	3
Find Pressure	5
Case 01: Air Pipeline Pressure Loss	6
Case 02: Gas Pipeline Outlet Pressure	7
Case 03: Gas Pipeline Inlet Pressure	8
Case 04: Methane Compressor to Processing Unit	9
Case 05: Natural Gas Pipeline Inlet Pressure	10
Case 06: Gas Pipeline Outlet Pressure vs Length	11
Case 07: Fifty Mile Long Pipeline Inlet Pressure	13
Case 08: Air Pressure Drop in Steel Pipe	14
Case 09: Air Flowing through Horizontal Pipe	15
Case 10: Gas Pipeline Inlet Pressure vs Flow Rate	16
Case 11: Air – Flow Through 100m Lengths of Steel Pipes	18
Case 12: Air – Flow Through 100ft Lengths of Steel Pipes	19
Find Flow	20
Case 01: Mass Flow of Air	21
Case 02: Gas Pipeline Flow Rate	22
Case 03: IGT (Institute of Gas Technology) Equation Flow Rate	23
Case 04: Flow Rate of Natural Gas Through Pipeline	24
Case 05: Pumping Hydrogen Gas from a Reservoir	25
Case 06: Carbon Dioxide – Flow Through a Pipe	26
Find Diameter	27
Case 01: Minimum Pipe Diameter	28
Case 02: Natural Gas Flow Rate vs Pressure Drop In Steel Pipe	29
Case 03: Diameter of an Air Pipeline	30
Case 04: Designing a Free Air Pipeline	31
Find Length	32
Case 01: Length of a Wrought Iron Pipe	33
Case 02: Compressor Stations for a Gas Transmission Pipeline	34
Case 03: Length of Steel Air Pipe	35
References	36

Introduction



Pipe Flow Wizard is a software application that performs flow rate and pressure drop calculations for fluid flow in a pipe. The Pipe Flow Wizard software can 'Find Pressure Drop', 'Find Flow Rate', 'Find Diameter Size', and 'Find Length of Pipe' depending on the information available.

Each of the **Find Pressure**, **Find Flow**, **Find Diameter** and **Find Length** calculations produced by the Pipe Flow Wizard software can be verified by comparison against published results data for compressible gas systems. The information in this document provides a general description of a published problem, the **Reference Source**, the **Published Results Data**, the **Pipe Flow Wizard Results Data** and a commentary on the results obtained for pressure drops, flow rates, diameter sizes and pipe lengths.

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

Calculations

Fluid Properties for the pressure condition at the start of each pipe are calculated from the user defined fluid data using the **Ideal Gas Law** plus any specified **Compressibility Factor Z** to establish the density of the gas.

Ideal Gases are considered to be perfectly elastic. Ideal gases follow Boyle's Law & Charles's Law thus the gas density at various points in the system can be calculated using these equations.

Real Gases behave according to a modified version of the ideal gas law. The modifying factor is known as the **Gas Compressibility Factor Z**. Where natural gas pressures are higher than 115 psi.a (800 kPa.a) the gas compressibility factor may not be close to 1.00, so it can be advisable to use a gas compressibility factor based on the pressure in the pipe.

There are different methods that can be used to calculate a gas compressibility factor for a specific pressure condition. The California Natural Gas Association (CNGA) method provides such a calculation for natural gas. The Pipe Flow Wizard software includes the option to automatically use the CNGA method to determine the natural gas compressibility for the average conditions in each pipe. The CNGA factor is then applied when calculating the gas flow rate using a specific Isothermal Flow Equation that allows for gas compressibility. The CNGA compressibility factor is only applicable to natural gas and is not applicable to other gases such as air etc.

The General Fundamental Isothermal Flow Equation (sometimes known as just the **General Flow equation** or the **Fundamental Flow equation**) provides perhaps the most universal method for calculating isothermal flow rates, however it relies on the inclusion of an accurate friction factor. The Pipe Flow Wizard software calculates an accurate friction factor using the Colebrook-White equation.

In addition to the **General Flow Equation**, Pipe Flow Wizard provides the functionality to allow calculations based on alternative equations such as:

The **Complete Isothermal Flow Equation (as defined in Crane Technical Paper 410)**,

The **AGA Isothermal Flow Equation**,

The **Weymouth Isothermal Flow Equation**,

The **Panhandle A Isothermal Flow Equation**,

The **Panhandle B Isothermal Flow Equation**.

The **IGT Isothermal Flow Equation**.

Each of these equations can be used to calculate isothermal flow rates in pipes. Most of these equations use a Pipeline Efficiency factor (instead of a friction factor) and a Compressibility Factor. The software allows the user to specify the factors that are used in the calculations.

Software Releases

The latest release of the Pipe Flow Wizard software has been completely rewritten to support use on Microsoft Windows (PCs), Mac OS (Apple Computers), and iOS (Apple Mobile Devices), including iPhone and iPad.

The original Pipe Flow Wizard software for Windows was released over 15 years ago and today **Pipe Flow Wizard software is 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.

Find Pressure



Case 01: Air Pipeline Pressure Loss

Reference: Fluid Mechanics and Hydraulics, 3rd Ed, 1994, McGraw-Hill; R. V. Giles, J. B. Evett PhD, C. Liu, page 238, Example 11.2

Pipe Flow Wizard Software: Find_Pressure_Case_01_Air_Pipeline_Pressure_Loss.pfw

Calculation Problem:

Air at 18 °C flows isothermally through a 300 mm diameter pipe at a flow rate of 0.450 kN/s (equivalent to 45.887 kg/s). The pipe is smooth (friction factor = 0.0080).

If the pressure at the entry point is 550 kPa, find the pressure at a point 200 m downstream.

The calculation method used for the published data was based on the Complete Isothermal equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 18 °C, 0.0 kPa.g, Viscosity 0.0181 Centipoise.
Fluid Data: Software will calculate the compressed gas properties.
Pipe Data: Internal roughness 0.000001 mm
 Friction factor=0.008014
Flow Rate: 45.887 kg/s (equivalent to 0.450 kN/s).

Calculation Method: Complete Isothermal Flow equation.

Standard Atmospheric Conditions: 20°C, 101.325 kPa.

Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published data stated the flow rate as a weight in kN/s rather than as a gas flow at standard conditions. $\text{Kg/s} = (\text{kN/s}) \times (1000/\text{g})$ where g is acceleration due to gravity, normally 9.80665 m/s², hence a mass flow rate of 45.887 kg/s was used in the Pipe Flow Wizard calculation.

The screenshot shows the 'FindPressure' software interface. The 'Results' tab is active, displaying a table of calculated parameters. The 'Entry Pressure' is set to 550.000000 kPa a, and the 'Exit Pressure' is calculated as 231.276217 kPa a. The 'Pressure Drop' is 318.723783 kPa. Other parameters include: Calc. Method (Complete Isothermal), Material (PVC (ANSI) Sch. 40), Internal Diameter (300 mm), Length (200 m), Elevation Change (0 m), Fluid (18°C) (Air), Compressed@ (550 kPa a), Density (6.585887 kg/m³), Viscosity (0.018 Centipoise), Mass Flow (45.887 kg/sec), Standard Flow (137087.252554 SCMH), Compressed Flow (6.967475 m³/sec), Flow Type (Turbulent), Reynolds Number (10819471), Friction Factor (0.008014), Exit Velocity (234.409234 m/sec), Exit Flow Compressed (16.569412 m³/sec), Friction Loss (318.723783 kPa), Fittings Loss (0.000000 kPa), and Elevation Loss (0.000000 kPa). The 'Pressure Drop' is highlighted with an orange box.

The published data relied on iteration of the downstream pressure value, until it produced an approximate balance when used in the gas flow equation, after which further iteration refinements were stopped.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Pressure Drop (kPa)	317	318.72
Pressure 200m Downstream (kPa)	233	231.28

Case 02: Gas Pipeline Outlet Pressure

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon Chapter 2, page 65 Example 15

Pipe Flow Wizard Software: Find_Pressure_Case_02_Natural_Gas_Pipeline_Outlet_Pressure.pfw

Calculation Problem:

Calculate the outlet pressure in a 15 mile natural gas pipeline, with an internal pipe diameter of 15.5 inches, where the required gas flow rate is 100 MMSCFD and the inlet pressure is 1000 psi absolute.

The pipeline efficiency value is 0.92.

The average gas temperature is 80 °F.

Gas gravity = 0.6, viscosity = 0.000008 lb/ft-sec.

Use the CNGA method to calculate gas compressibility factor Z.

The calculation method used for the published data was based on the Panhandle A equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas Specific Gravity 0.6 (0.045 lb/ft³)
Viscosity 0.0119 centipoise (0.000008 lb/ft-sec)
@ 80 °F, 0.00 psi.g

Fluid Data: Software will calculate the compressed gas properties.

Pipe Data: Pipeline efficiency = 0.92.

Calculation Method: Panhandle A Isothermal equation.

Standard Atmospheric Conditions: 60 °F, 14.696 psi.a

Gas Model: Real Gas (Ideal Gas Law & CNGA compressibility factor)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Outlet Pressure (psi absolute)	968.35	968.19
Pressure Drop (psi)	31.65	31.81

The screenshot shows the 'FindPressure' software interface. The 'Results' window is open, displaying various input and output parameters. The 'Exit Pressure' is highlighted with an orange box, showing a value of 968.186477 psi a. Other parameters include: Calc. Method (Panhandle A Isothermal), Material (Steel Sch. 10), Internal Diameter (15.5 inch), Length (79200 ft), Elevation Change (0 ft), Fluid (80°F) (Natural Gas), Compressed@ (1000 psi a), Density (3.504895 lb/ft³), Viscosity (16.556188 Centistokes), Standard Flow (100 MMSCFD), Mass Flow (24.463493 kg/sec), Compressed Flow (15.387842 ft³/sec), Flow Type (Turbulent), Reynolds Number (6648386), Friction Factor (0.010843), Exit Velocity (12.179753 ft/sec), Entry Pressure (1000.000000 psi a), Entry Density (3.504895 lb/ft³), Exit Density (3.379274 lb/ft³), Exit Flow Compressed (15.959867 ft³/sec), Friction Loss (31.813523 psi), Fittings Loss (0.000000 psi), Elevation Loss (0.000000 psi), and Pressure Drop (31.813523 psi). A 'CLOSE RESULTS' button is at the bottom.

Case 03: Gas Pipeline Inlet Pressure

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon Chapter 2, page 67 Example 16

Pipe Flow Wizard Software: Find_Pressure_Case_03_Natural_Gas_Pipeline_Inlet_Pressure.pfwp

Calculation Problem:

Calculate the inlet pressure in a 24 km natural gas pipeline, with internal diameter 288 mm.

The gas flow rate is 3.5 Mm³/day and the final delivery pressure is 6000 kPa absolute. The average gas temperature is 20 °C, the pipeline efficiency is 0.92 and the compressibility factor is 0.90.

The calculation method used for the published data was based on the Panhandle A equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas Specific Gravity 0.6 (0.723 kg/m³)
Viscosity 0.0119 centipoise
@ 20 °C, 0.00 kPa.g

Fluid Data: Software calculates compressed gas properties.

Pipe Data: Pipeline efficiency = 0.92.

Flow Rate: 3.5 MMSCMD.

Calculation Method: Panhandle A Isothermal equation,
Standard Atmospheric Conditions: 15 °C, 101.325 kPa.
Gas Model: Real Gas (Ideal Gas Law with compressibility Z=0.9)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The publication states the gas flow rate is 3.5 Mm³/day. Here, the 'M' stands for 'one million', which is not the same as the 'M' in "standard condition" units i.e. MSCMD. In "standard condition" units a single 'M' stands for 'one thousand', and 'MM' stands for one million.

FindPressure

Results

Calc. Method: Panhandle A Isothermal

Material: Steel N/A

Internal Diameter: 288 mm

Length: 24000 m

Elevation Change: 0 m

Fluid (20°C): Natural Gas

Compressed@: 7479.585 kpa a

Density: 59.300271 kg/m³

Viscosity: 0.0119 Centipoise

Standard Flow: 3.5 MMSCMD

Mass Flow: 29.796405 kg/sec

Compressed Flow: 0.502467 m³/sec

Flow Type: Turbulent

Reynolds Number: 11069667

Friction Factor: 0.011192

Exit Velocity: 9.615206 m/sec

Pressure:

Entry Pressure: 7479.585000 kpa a

Exit Pressure: 6000.000014 kpa a

Entry Density: 59.300271 kg/m³

Exit Density: 47.569702 kg/m³

Exit Flow Compressed: 0.626374 m³/sec

Friction Loss: 1479.584986 kPa

Fittings Loss: 0.000000 kPa

Elevation Loss: 0.000000 kPa

Pressure Drop: 1479.584986 kPa

CLOSE RESULTS

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Inlet Pressure (kPa absolute)	7471	7480
Delivery Exit Pressure (kPa absolute)	6000	6000
Pressure Drop (kPa)	1471	1479

Case 04: Methane Compressor to Processing Unit

Reference: Chemical Engineering Volume 1, 6th Ed, 1999,
Elsevier, J M Coulson, J F Richardson, page 168 Example 4.3

Pipe Flow Wizard Software: Find_Pressure_Case_04_Methane_Compressor_Flow_Rate.pfwp

Calculation Problem:

A flow of 50 m³/s (180000 m³/h) of methane, starting at a temperature of 288 K and 101.3 kN/m² must be delivered along a 0.6 m diameter line, 3.0 km long with a relative roughness of 0.0001, linking a compressor and a processing unit.

The delivery pressure is to be 170 kN/m² (170 kPa) and the delivery temperature 288 K. The methane leaves the compressor at 297 K.

What pressure is needed at the compressor to achieve this flow rate?

The calculation method used for the published data was based on the Complete Isothermal equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Methane at 293 K average, 0.00 kPa.g,
Density 0.667218 kg/m³
Viscosity 0.0108 centipoise.

Fluid Data: Software will calculate the compressed gas properties.

Pipe Data: Absolute roughness 0.06 mm.

Calculation Method: Complete Isothermal Flow equation.

Standard Atmospheric Conditions: 15°C, 101.325 kPa

Gas Model: Ideal Gas Law

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The screenshot shows the 'FindPressure' software interface. The 'Results' window is open, displaying various parameters and their calculated values. The 'Entry Pressure' is highlighted with an orange box.

Parameter	Value	Unit
Calc. Method	Complete Isothermal	
Material	Steel (ANSI) Sch. 40	
Internal Diameter	600	mm
Length	3000	m
Elevation Change	0	m
Fluid (19.85°C)	Methane	
Compressed@	408.203	kPa a
Density	2.687988	kg/m ³
Viscosity	0.010975	Centipoise
Standard Flow	180000	SCMH
Mass Flow	33.922414	kg/sec
Compressed Flow	445.671149	ft ³ /sec
Flow Type	Turbulent	
Reynolds Number	6559052	
Friction Factor	0.012251	
Exit Velocity	107.170460	m/sec
Pressure		
Entry Pressure	408.203000	kPa a
Exit Pressure	170.007517	kPa a
Entry Density	2.687988	kg/m ³
Exit Density	1.119488	kg/m ³
Exit Flow Compressed	1070.095623	ft ³ /sec
Friction Loss	238.195483	kPa
Fittings Loss	0.000000	kPa
Elevation Loss	0.000000	kPa
Pressure Drop	238.195483	kPa

At the bottom of the window, there is a button labeled 'CLOSE RESULTS'.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Entry Pressure Required (kPa absolute)	405.00	408.203
Compressor Pressure (N/m ²)	405000	408203

Case 05: Natural Gas Pipeline Inlet Pressure

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon, Chapter 3, page 118 Example 8, First part.

Pipe Flow Wizard Software: Find_Pressure_Case_05_Natural_Gas_Pipeline.pfwp

Calculation Problem:

A natural gas pipeline, internal diameter 476 mm, is 60 km long.
The gas flow rate is 5.0 Mm³/day at 20 °C.
The pipe roughness is 0.015 mm.
Gas gravity is 0.65 and the compressibility factor is 0.88.

Calculate the inlet pressure required to achieve a delivery pressure of 4 MPa.a (4000 kPa.a).

The calculation method used for the published data was the General Flow equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Natural Gas
Specific Gravity 0.65 (0.783 kg/m³)
Viscosity 0.0119 centipoise
@ 20 °C, 0.0 bar.g

Fluid Data: Software calculates the compressed gas properties.

Pipe Data: Absolute roughness 0.015 mm.

Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 15°C, 101.325 kPa.
Gas Model: Real Gas (Ideal Gas Law & compressibility Z=0.88)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Inlet pressure (MPa absolute)	5.077	5.07795
Pressure Drop (MPa)	1.077	1.07795
Delivery Pressure (MPa)	4.0	4.0

FindPressure

Results

Calc. Method: General Fundamental

Z Model: Custom Compressibility Factor

Z = 0.88

Material: Steel (ANSI) Sch. 40

Internal Diameter: 476 mm

Length: 60000 m

Elevation Change: 0 m

Fluid: Natural Gas

Temperature: 20 °C

Compressed@: 5077.949 kPa a

Density: 44.605607 kg/m³

Viscosity: 0.0119 Centipoise

Standard Flow: 5 MMSCMD

Mass Flow: 46.113484 kg/sec

Compressed Flow: 3721.696783 m³/hour

Flow Type: Turbulent

Reynolds Number: 10365354

Friction Factor: 0.010150

Velocity: 5.809446 m/sec (Entry), 7.375016 m/sec (Exit)

Pressure: 5077.949000 kPa a (Entry), 4000.000608 kPa a (Exit)

Entry Density: 44.605607 kg/m³

Exit Density: 35.136717 kg/m³

Exit Flow Compressed: 4724.645896 m³/hour

Friction Loss: 1077.948392 kPa

Fittings Loss: 0.000000 kPa

Elevation Loss: 0.000000 kPa

Pressure Drop: 1077.948392 kPa

CLOSE RESULTS

Case 06: Gas Pipeline Outlet Pressure vs Length

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon Chapter 2, page 80

Pipe Flow Wizard Software: Find_Pressure_Case_06_Outlet_Pressure_vs_Length.pfw

Calculation Problem:

For a gas pipeline, 100 miles in length and 15.5 inch internal diameter, use different flow equations to compare the outlet pressure at points 25 miles, 50 miles, 75 miles and 100 miles downstream from the start of the pipe for a gas flow rate of 100 MMSCFD.

The gas temperature is 80 °F, and the upstream pressure at the start of the pipe is fixed at 1400 psi.g.

The published data compares 5 different calculation equations: Panhandle A, Panhandle B, General with Colebrook-White, AGA and Weymouth. For details of pipeline efficiency and gas compressibility see comments in results table.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Natural Gas
Specific Gravity 0.6 (0.044 lb/ft³)
Viscosity 0.0119 centipoise
@ 80 °F, 0.0 psi.g

Fluid Data: Software calculates the compressed gas properties.

Pipe Data: Roughness 700 micro-inches.

Calculation method: Various isothermal flow equations.
Standard Atmospheric Conditions: 60 °F, 14.696 psi.a.
Gas Model: Real Gas (Ideal Gas Law & CNGA compressibility factor)

A pipeline efficiency value of 0.95 was used in the Panhandle and Weymouth equations. The General Fundamental Isothermal Flow equation used Colebrook-White friction factors. The CNGA compressibility factor was used with all isothermal flow equations except for the AGA Ideal Gas Case.

Commentary:

See the Results Comparison Tables that follow.

The published results specified a pipe roughness (700 μ inches) for use in both the AGA & General Flow equations (with Colebrook-White friction factors) and a pipeline efficiency of 0.95 for used in the Panhandle & Weymouth equations. Reference to IR=0.0007 in the comparison tables means an internal roughness of 700 μ inches.

The published data did not specify if a compressibility factor had been used in the calculations, however most of the other example calculations in the published work included a compressibility factor. In the Pipe Flow Wizard software, the CNGA (Californian Natural Gas Association) method for automatic calculation of the compressibility factor was selected. The calculated results compare well with the published graph readings, indicating that a compressibility factor was used in the calculation of the published data for all equations except the published AGA results, which appear to have been based on assumption of the Ideal Gas Law with no compressibility.

The screenshot shows the 'FindPressure' software interface with the 'Results' tab selected. The window displays various input and calculated parameters for a gas pipeline. The 'Exit Pressure' is highlighted with an orange border.

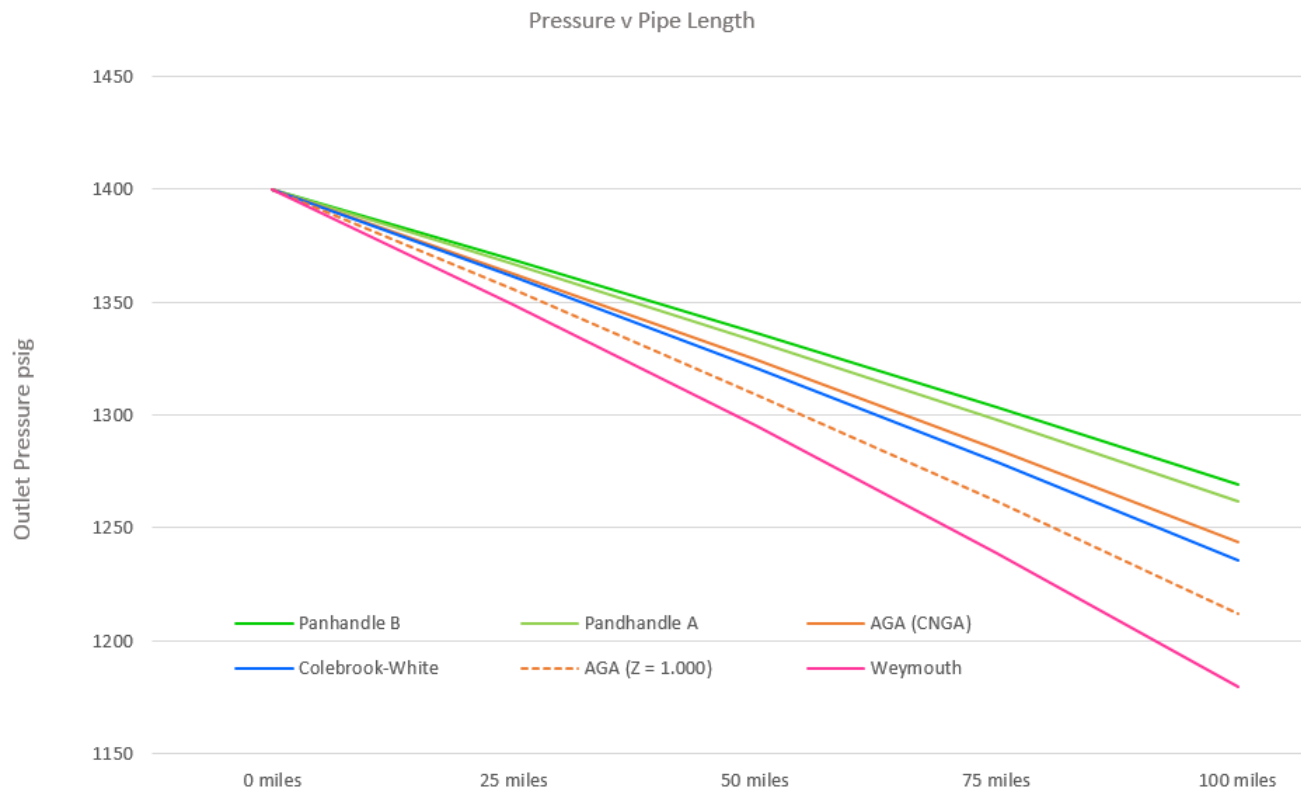
FindPressure		
Results		
Calc. Method	Panhandle B Isothermal	
Efficiency	0.95	
Z Model	CNGA Compressibility Factor	
Z =	Calculated	
Material	Steel (ANSI) Sch. 40	
Internal Diameter	15.5	inch
Length	132000	ft
Elevation Change	0	ft
Fluid (80°F)	Natural Gas	
Compressed@	1400	psi g
Standard Flow	100	MMSCFD
Mass Flow	23.988627	kg/sec
Compressed Flow	10.403499	ft³/sec
Flow Type	Turbulent	
Reynolds Number	6519332	
Friction Factor	0.010852	
Exit Velocity	8.149696	ft/sec
Pressure		
Entry Pressure	1400.000000	psi g
Exit Pressure	1368.662545	psi g
Entry Density	5.083469	lb/ft ³
Exit Density	4.952306	lb/ft ³
Exit Flow Compressed	10.679039	ft ³ /sec
Friction Loss	31.337455	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	31.337455	psi
CLOSE RESULTS		

Result Comparison:**Published Graph Readings of Outlet Pressures (Psi.g):**

Formula	Panhandle B	Panhandle A	General Colebrook-White	AGA	AGA Ideal Gas	Weymouth
Friction	Effic. = 0.95	Effic. = 0.95	IR =0.0007in	IR =0.0007in	IR =0.0007in	Effic. = 0.95
Assumed Compressibility	CNGA factor	CNGA factor	CNGA factor	CNGA factor	Ideal gas Z = 1.000	CNGA factor
25 miles	1368	1365	1359	Not available	1353	1345
50 miles	1335	1330	1318	Not available	1305	1289
75 miles	1303	1295	1276	Not available	1258	1234
100 miles	1270	1260	1235	Not available	1210	1178

Pipe Flow Wizard Calculated Results of Outlet Pressures (Psi.g):

Formula	Panhandle B	Panhandle A	General Colebrook-White	AGA	AGA Ideal Gas	Weymouth
Friction	Effic. = 0.95	Effic. = 0.95	IR =0.0007in	IR =0.0007in	IR =0.0007in	Effic. = 0.95
Compressibility	CNGA factor	CNGA factor	CNGA factor	CNGA factor	Ideal gas Z = 1.000	CNGA factor
25 miles	1368.66	1366.93	1361.00	1362.82	1355.35	1348.72
50 miles	1336.48	1332.91	1320.67	1324.42	1309.20	1295.10
75 miles	1303.37	1297.86	1278.88	1284.71	1261.38	1238.81
100 miles	1269.27	1261.69	1235.46	1243.54	1211.69	1179.44

Graphical Comparison of Formula:

Case 07: Fifty Mile Long Pipeline Inlet Pressure

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon, Chapter 3, page 87 Example 1, Case A

Pipe Flow Wizard Software: Find_Pressure_Case_07_Pipe_Inlet_Pressure_50Miles.pfwp

Calculation Problem:

A gas pipeline, 15.5 inch internal diameter, 50 miles long, transports natural gas (SG = 0.6 and viscosity = 0.0119 centipoise) at a flow rate of 100 MMSCFD at an inlet temperature of 60 °F.

Assuming isothermal flow, calculate the inlet pressure required if the required delivery pressure at the pipeline terminus is 870 psi.g.

Case A: No elevation changes along the pipeline length.

The calculation method used for the published data was based on the General Flow equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Natural Gas
Specific Gravity 0.6 (0.04582 lb/ft³)
Viscosity 0.01191 centipoise
@ 60 °F, 14.696 psi.a

Fluid Data: Software will calculate the compressed gas properties.

Pipe Data: Absolute roughness 0.0007 inches.

Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 60 °F, 14.696 psi.a
Gas Model: Real Gas (Ideal Gas Law with CNGA calculated compressibility factor).

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published result was calculated using a compressibility factor of 0.8662, which was derived using the CNGA formula. The Pipe Flow Wizard software automatically calculated the same CNGA 0.8662 compressibility factor.

The screenshot shows the 'FindPressure' software window with the 'Results' tab selected. The 'Calc. Method' is set to 'General Fundamental'. The 'Z Model' is 'CNGA Compressibility Factor' with a value of 0.8662. The 'Material' is 'Steel (ANSI) Sch. 40'. The 'Internal Diameter' is 15.5 inch, 'Length' is 264000 ft, and 'Elevation Change' is 0 ft. The 'Fluid (60°F)' is 'Natural Gas'. The 'Compressed@' pressure is 985.617 psi.g, with 'Density' at 3.630339 lb/ft³ and 'Viscosity' at 0.0119 Centipoise. The 'Atmosphere' is 14.695949 psi.a. The 'Standard Flow' is 100 MMSCFD, 'Mass Flow' is 53.034732 lb/sec, and 'Compressed Flow' is 1489226.053968 l/hour. The 'Flow Type' is 'Turbulent', 'Reynolds Number' is 6537683, and 'Friction Factor' is 0.010851. The 'Exit Velocity' is 12.817407 ft/sec. The 'Pressure' section shows 'Entry Pressure' at 985.617000 psi.g, 'Exit Pressure' at 870.000032 psi.g, 'Entry Density' at 3.630339 lb/ft³, and 'Exit Density' at 3.157690 lb/ft³. The 'Exit Flow Compressed' is 1712136.297769 l/hour. The 'Friction Loss' is 115.616968 psi, 'Fittings Loss' is 0.000000 psi, and 'Elevation Loss' is 0.000000 psi. The 'Pressure Drop' is 115.616968 psi. A 'CLOSE RESULTS' button is at the bottom.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Inlet Pressure (psi.g) for Case A	985.66	985.62

Case 08: Air Pressure Drop in Steel Pipe

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, Chapter 5, page 265 Example 5.8

Pipe Flow Wizard Software: Find_Pressure_Case_08_Air_Flow_Pressure_Drop.pfwp

Calculation Problem:

Air flows at velocity of 50 ft/s in a 2" inside diameter pipe at 80°F, at an initial pressure of 100 psi.g. If the pipe is horizontal and 1000 ft long, calculate the pressure drop if the flow is isothermal.

Use a friction factor of 0.02. The calculation method used for the published data was based on the General Isothermal Flow Equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 80 °F, 0.0 psi.g
Density 0.0736 lb/ft³, Viscosity 0.0185 centipoise.
Fluid Data: Software calculates the compressed gas properties.
Pipe Data: Internal Roughness 0.001853 inches (Steel Sch. 40)

Calculation Method: General Isothermal Flow equation.

Standard Atmospheric Conditions: 60°F, 14.696 psi.a

Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The normal pipe roughness for mild steel pipe is 0.001811 inches, however this was adjusted to 0.001853 inches to give a friction factor of 0.02 as assumed in the published text.

Although the fluid data is defined for 80°F and 0.0 psi.g, the Pipe Flow Wizard software's compressible flow calculation engine automatically accounts for compression of the air to the 100 psi.g starting condition.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Outlet Pressure (psi.a)	94.18	94.178
Pressure Drop (psi)	20.52	20.518

The screenshot shows the 'FindPressure' software interface. The 'Results' window is open, displaying various calculated parameters. The 'Exit Pressure' is highlighted with a red box, showing a value of 94.178154 psi.a. The 'Pressure Drop' is also highlighted with a red box, showing a value of 20.517795 psi. Other parameters include Entry Pressure (114.695949 psi.a), Exit Velocity (60.935355 ft/sec), Reynolds Number (384523), Friction Factor (0.020070), and Mass Flow (0.6265 lb/sec).

Parameter	Value	Units
Calc. Method	General Fundamental	
Material	Steel (ANSI) Sch. 40	
Internal Diameter	2	inch
Length	1000	ft
Elevation Change	0	ft
Fluid (80°F)	Air	
Compressed@	114.695949	psi a
Density	0.573934	lb/ft ³
Viscosity	15.724566	Centistokes
Mass Flow	0.6265	lb/sec
Standard Flow	0.000836	MMSCMH
Compressed Flow	111277.204517	l/hour
Flow Type	Turbulent	
Reynolds Number	384523	
Friction Factor	0.020070	
Exit Velocity	60.935355	ft/sec
Pressure		
Entry Pressure	114.695949	psi a
Exit Pressure	94.178154	psi a
Entry Density	0.573934	lb/ft ³
Exit Density	0.471264	lb/ft ³
Exit Flow Compressed	135520.224561	l/hour
Friction Loss	20.517795	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	20.517795	psi

Case 09: Air Flowing through Horizontal Pipe

Reference: Elementary Fluid Mechanics, 1940
John Wiley & Sons, Inc., John K. Vennard, page 163 “Illustrative Problem”

Pipe Flow Wizard Software: Find_Pressure_Case_09_Air_Through_Horizontal_Pipe.pfwp

Calculation Problem:

Air is pumped from a reservoir at 50 psi.a through a clean horizontal smooth pipe 3” in diameter and 2000 ft long. The conditions of flow are isothermal and the temperature of the gas is 100 degrees F.

With a flow rate of 40 lb/min what is the pressure 2000 ft downstream?

The calculation method used for the published data was the Simplified version of the Complete Isothermal Equation, which neglects the term $2 \ln(V_2/V_1)$ since this is normally small compared to $f^*(L/D)$.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 100 °F, 0.0 psi.g
Density 0.071 lb/ft³, Viscosity 0.0191 centipoise.
Fluid Data: Software calculates the compressed gas properties.
Pipe Data: Internal diameter 3 inches
Internal roughness 0.000001 inches.

Calculation Method: Complete Isothermal Flow equation.

Standard Atmospheric Conditions: 68 °F, 14.696 psi.a

Gas Model: Ideal Gas Law

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published result was calculated using a friction factor of 0.0145 (which was read from a graph).

The Pipe Flow Wizard software used a pipe roughness of 0.000001 inches, calculating a friction factor of 0.014818.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Pressure 2000 feet downstream (psi.a)	39.3	38.959
Friction Factor	0.0145	0.014818

The screenshot shows the 'FindPressure' software interface. The 'Results' window is open, displaying various parameters and their calculated values. The 'Exit Pressure' is highlighted with an orange box, showing a value of 38.959170 psi.a. Other parameters include Mass Flow (40 lb/min), Standard Flow (531.842307 SCFM), and Compressed Flow (281693.143437 l/hour). The 'Pressure Drop' is also shown as 11.040830 psi.

Parameter	Value	Units
Calc. Method	Complete Isothermal	
Material	Copper DWV Drain,Waste,Vent	
Internal Diameter	3	inch
Length	2000	ft
Elevation Change	0	ft
Fluid (100°F)	Air	
Compressed@	50	psi a
Density	0.241257	lb/ft ³
Viscosity	16.77834	Centistokes
Mass Flow	40	lb/min
Standard Flow	531.842307	SCFM
Compressed Flow	281693.143437	l/hour
Flow Type	Turbulent	
Reynolds Number	265126	
Friction Factor	0.014818	
Exit Velocity	72.246913	ft/sec
Pressure		
Entry Pressure	50.000000	psi a
Exit Pressure	38.959170	psi a
Entry Density	0.241257	lb/ft ³
Exit Density	0.187983	lb/ft ³
Exit Flow Compressed	361523.543165	l/hour
Friction Loss	11.040830	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Pressure Drop	11.040830	psi

Case 10: Gas Pipeline Inlet Pressure vs Flow Rate

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon Chapter 2, page 81

Pipe Flow Wizard Software: Find_Pressure_Case_10_Inlet_Pressure_vs_Flow_Rate.pfwp

Calculation Problem:

For a 100 mile long gas pipeline, 29.0 inch internal diameter, use different flow equations to compare the inlet pressure for gas flow rates of 200, 300, 400, 500 and 600 MMSCFD.

The gas temperature is 80 °F, and the delivery pressure at the end of the pipe is fixed at 800 psi.g.

The published data used 5 different calculation methods for comparison: Panhandle A, Panhandle B, General with Colebrook-White, AGA and Weymouth. For details of pipeline efficiency and gas compression see comments in results table.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas specific gravity 0.6 at 80 °F, 0.00 psi.g, Density 0.044 lb/ft³, Viscosity 0.0119 centipoise.

Fluid Data: Software calculates compressed gas properties.

Pipe Data: Roughness 700 micro-inches.

Calculation Method: Various Isothermal flow equations.

Standard Atmospheric Conditions: 60 °F, 14.696 psi.a

Gas Model: Real Gas (Ideal Gas Law with CNGA compressibility)

The General Fundamental Flow equation used Colebrook-White friction factors. The Panhandle and Weymouth equations used a pipeline efficiency value of 0.95.

The CNGA compressibility factor was used with all isothermal flow equations except for the AGA Ideal Gas case.

Commentary:

See the Results Comparison Table to compare data for each of the different flow rates specified in the calculation problem.

The published results specified a pipe roughness (700 μ inches) for use in both the AGA & General Flow equations (with Colebrook-White friction factors) and a pipeline efficiency of 0.95 for use in the Panhandle & Weymouth equations. Reference to IR=0.0007in in the results means an internal roughness of 700 μ inches was used.

The published data did not specify if a compressibility factor had been used in the calculations, however most of the other example calculations in the published work included a compressibility factor. In the Pipe Flow Wizard software, the CNGA (Californian Natural Gas Association) method for automatic calculation of the compressibility factor was selected. The calculated results compare well with the published graph readings, indicating that a compressibility factor was used in the calculation of the published data for all equations except the published AGA results, which appear to have been based on assumption of the Ideal Gas Law with no compressibility.

FindPressure

Results

Calc. Method: General Fundamental
 Z Model: CNGA Compressibility Factor
 Z = 0.8949
 Material: Steel (ANSI) Sch. 40
 Internal Diameter: 29 inch
 Length: 528000 ft
 Elevation Change: 0 ft
 Fluid (80°F): Natural Gas
 Compressed@: 842.2217 psi g
 Density: 2.87458 lb/ft³
 Viscosity: 0.0119 Centipoise
 Atmosphere: 14.695949 psi a
 Standard Flow: 200 MMSCFD
 Mass Flow: 102.421206 lb/sec
 Compressed Flow: 35.629974 ft³/sec

Flow Type: Turbulent
 Reynolds Number: 6748186
 Friction Factor: 0.010038
 Exit Velocity: 8.214515 ft/sec
 Pressure: 842.221700 psi g
 Exit Pressure: 800.000007 psi g
 Entry Density: 2.874580 lb/ft³
 Exit Density: 2.718220 lb/ft³
 Exit Flow Compressed: 37.679515 ft³/sec
 Friction Loss: 42.221693 psi
 Fittings Loss: 0.000000 psi
 Elevation Loss: 0.000000 psi
 Pressure Drop: 42.221693 psi

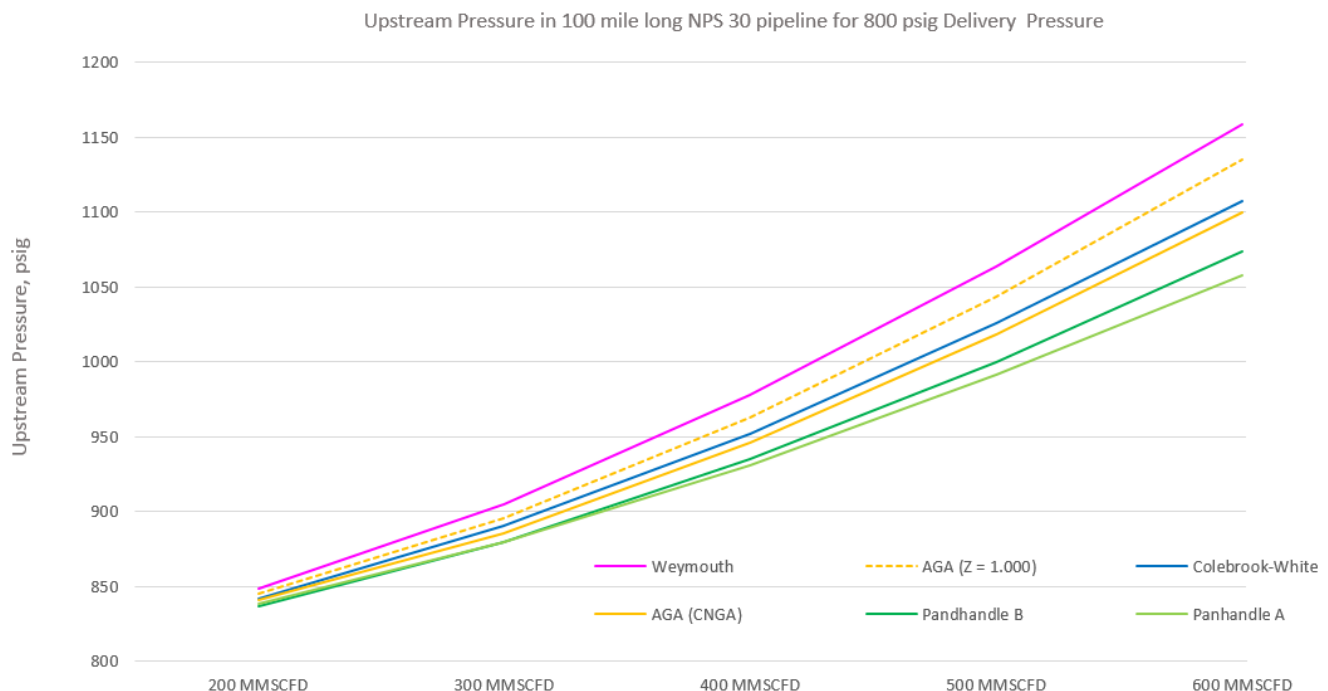
CLOSE RESULTS

Results Comparison:**Published Graph Readings of Inlet Pressures (Psi.g):**

Formula	Panhandle A	Panhandle B	General Colebrook-White	AGA	AGA Ideal Gas	Weymouth
Friction	Effic.=0.95	Effic.=0.95	IR=0.0007in	IR=0.0007in	IR=0.0007in	Effic.=0.95
Assumed Compressibility	CNGA factor	CNGA factor	CNGA factor	CNGA factor	Ideal gas Z = 1.000	CNGA factor
200 MMSCFD	837	837	844	Not available	846	850
300 MMSCFD	882	882	894	Not available	900	909
400 MMSCFD	942	947	960	Not available	977	987
500 MMSCFD	1010	1020	1040	Not available	1060	1080
600 MMSCFD	1074	1093	1132	Not available	1156	1172

Pipe Flow Wizard Calculated Results of Inlet Pressures (Psi.g):

Formula	Panhandle A	Panhandle B	General Colebrook-White	AGA	AGA Ideal Gas	Weymouth
Friction	Effic. = 0.95	Effic. = 0.95	IR =0.0007in	IR =0.0007in	IR =0.0007in	Effic. = 0.95
Compressibility	CNGA factor	CNGA factor	CNGA factor	CNGA factor	Ideal gas Z = 1.000	CNGA factor
200 MMSCFD	838.52	836.83	842.22	840.77	845.42	848.24
300 MMSCFD	879.52	879.32	890.07	885.53	895.30	904.63
400 MMSCFD	931.13	934.57	952.06	946.26	963.02	977.63
500 MMSCFD	991.03	1000.09	1025.33	1018.52	1043.74	1063.43
600 MMSCFD	1057.28	1073.64	1107.33	1099.75	1134.72	1158.78

Graphical Comparison of Formula:

Case 11: Air – Flow Through 100m Lengths of Steel Pipes

Reference: Flow of Fluids – Technical Paper No 410M, 1999, Crane Co. Appendix B-14.

Pipe Flow Wizard Software: Find_Pressure_Case_11_Air_Flow_Through_100m_Lengths_Of_Steel_Pipes.pfwp

Calculation Problem:

Compressed air at 7 bar gauge and 15°C flows through 100 meters long schedule 40 steel pipes.

Find the pressure drop in each of the following pipe sizes:
Steel Schedule 40 1.0", 1.5", 2.0", 2.5", 3.0"

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 15 °C, 7.0 bar.g,
Density 9.685785 kg/m³, Viscosity 0.018069 cP.
Fluid Data: Software calculates the compressed gas properties.
Pipe Data: Schedule 40 Steel, various sizes.
Roughness 0.046 mm.

Calculation Method: General Isothermal Flow equation.

Standard Atmospheric Conditions: 15 °C, 101.325 kPa absolute

Gas Model: Ideal Gas Law

Commentary:

The published data and the calculated results compare well but differ slightly, with pressure drop comparisons varying by up to 0.04 bar (or about 5.5% of the total pressure drop). We believe the published results were calculated using the Darcy-Weisbach equation (since Pipe Flow Wizard results produced using its non-compressible calculation engine give almost exactly the same figures), whereas the Pipe Flow Wizard results below were generated using the software's more accurate compressible calculation engine together with the General Fundamental Isothermal flow equation (which is better suited for compressible air flow calculations).

The screenshot shows the 'FindPressure' software interface. The 'Results' window is open, displaying the following data:

Calc. Method	General Fundamental
Material	Steel (ANSI) Sch. 40
Internal Diameter	26.645 mm
Length	100 m
Elevation Change	0 m
Fluid (15°C)	Air
Compressed@	7 bar g
Density	9.685785 kg/m ³
Viscosity	0.018069 Centipoise
Atmosphere	1.01325 bar a
Standard Flow	800 SLM
Mass Flow	0.979789 kg/min
Compressed Flow	6069.447478 l/hour
Flow Type	Turbulent
Reynolds Number	43186
Friction Factor	0.026285
Exit Velocity	3.040232 m/sec
Exit Pressure	6.956181 bar g
Exit Flow Compressed	6102.819533 l/hour
Friction Loss	0.043819 bar
Fittings Loss	0.000000 bar
Elevation Loss	0.000000 bar
Pressure Drop	0.043819 bar

At the bottom of the window, there is a button labeled 'CLOSE RESULTS'.

Results Comparison:

Pipe Details Steel Schedule 40	Free Air m ³ /min	Compressed Flow m ³ /min	Published Pressure Drop (Bar)	Pipe Flow Wizard Pressure Drop (Bar)
1.0" Diameter, 100 m long	0.800	0.101	0.044	0.0438
1-1/2" Diameter, 100 m long	10.000	1.264	0.640	0.6673
2.0" Diameter, 100 m long	20.000	2.528	0.685	0.71803
2-1/2" Diameter, 100 m long	32.000	4.046	0.682	0.7226
3.0" Diameter, 100 m long	30.000	3.793	0.197	0.2004

Case 12: Air – Flow Through 100ft Lengths of Steel Pipes

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Appendix B-15.

Pipe Flow Wizard Software: Find_Pressure_Case_12_Air_Flow_Through_100ft_Lengths_Of_Steel_Pipes.pfwp

Calculation Problem:

Compressed air at 100 psi gauge and 60°F flows through 100 feet long schedule 40 steel pipes.

Find the pressure drop in each of the following pipe sizes:
Steel Schedule 40 4.0", 6.0", 8.0", 10.0", 12.0"

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 60°F, 0 psi.g and,
Density 0.595574 lb/ft³, Viscosity 0.018095 cP.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Schedule 40 Steel, various sizes.
Roughness 0.001811 in.

Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 60 °F, 14.696 psi absolute
Gas Model: Ideal Gas Law

Commentary:

The published data and the calculated results compare well.

The density of air at 100 psi.g and 60°F used in the published results was not specified, and the published results were based on a non-compressible calculation since the pressure drop was small.

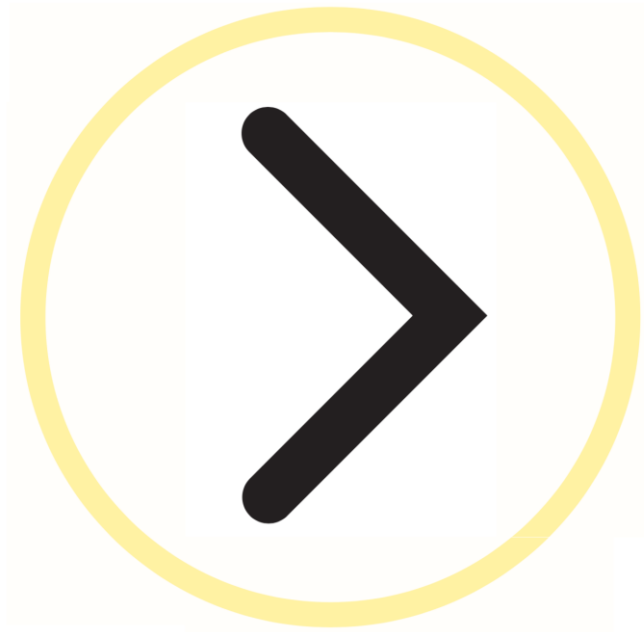
The Pipe Flow Wizard software automatically calculated the density of the compressed air at 100 psi.g to be 0.595574 lb/ft³ and it used this in the compressible flow equation to calculate the results.

The screenshot shows the 'FindPressure' software interface. The 'Results' tab is active, displaying a table of calculated parameters. The 'Calc. Method' is 'General Fundamental', 'Material' is 'Steel (ANSI) Sch. 40', 'Internal Diameter' is 4.026 inch, 'Length' is 100 ft, 'Elevation Change' is 0 ft, 'Fluid (60°F)' is 'Air', 'Compressed@' is 100 psi g, 'Density' is 0.595574 lb/ft³, 'Viscosity' is 0.018095 Centipoise, and 'Atmosphere' is 14.695949 psi a. The 'Standard Flow' is 650 SCFM, 'Mass Flow' is 48.849924 lb/min, and 'Compressed Flow' is 82.021587 ft³/min. Below this, a table lists 'Flow Type' (Turbulent), 'Reynolds Number' (254110), 'Friction Factor' (0.018154), 'Exit Velocity' (15.474523 ft/sec), 'Exit Pressure' (99.916764 psi g), 'Exit Flow Compressed' (82.081154 ft³/min), 'Friction Loss' (0.083236 psi), 'Fittings Loss' (0.000000 psi), and 'Elevation Loss' (0.000000 psi). The 'Pressure Drop' is highlighted in orange, showing 0.083236 psi. A 'CLOSE RESULTS' button is at the bottom.

Results Comparison:

Pipe Details Steel Schedule 40	Free Air ft ³ /min	Compressed Flow ft ³ /min	Published Data Pressure Drop (psi)	Pipe Flow Wizard Pressure Drop (psi)
4.0" Diameter, 100 ft long	650	83.3	0.086	0.0832
6.0" Diameter, 100 ft long	14000	1794	4.21	4.223
8.0" Diameter, 100 ft long	16000	2051	1.33	1.312
10.0" Diameter, 100 ft long	24000	3076	0.918	0.9029
12.0" Diameter, 100 ft long	28000	3588	0.505	0.4957

Find Flow



Case 01: Mass Flow of Air

Reference: Fluid Mechanics and Hydraulics, 3rd Ed, 1994, McGraw-Hill; R. V. Giles, J. B. Evett PhD, C. Liu page 237, Example 11.1

Pipe Flow Wizard Software: Find_Flow_Case_01_Mass_Flow_Air.pfwf

Calculation Problem:

Find the mass flow rate of air flowing isothermally through a 6-inch diameter pipe, at 65 °F, where the inlet pressure is 82 psi absolute, and at a distance of 550 feet downstream of the inlet, the pressure is 65 psi absolute.

The pipe surface is smooth (the problem specifies an assumed friction factor of 0.0095) and the calculation method used for the published data was the Complete Isothermal Flow equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 65 °F, 0.0 psi.g, Viscosity 0.0181 centipoise
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 0.000001 inches
 Friction factor = 0.00973

Calculation Method: Complete Isothermal Flow equation.

Standard Atmospheric Conditions: 68°F, 14.696 psi.a

Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published data used several rounded numbers in the calculation.

In the Pipe Flow Wizard software calculation, the pipe's internal roughness value was set to a very small value (much lower than the usual internal roughness for any of the common pipe materials). This was done to simulate the very "smooth" pipe that was used in the published literature (friction factor of 0.0095).

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Mass Flow (lb/sec)	14.5	14.379

The screenshot shows the FindFlow software interface with the following data:

FindFlow		
Results		
Calc. Method	Complete Isothermal	
Material	Steel (ANSI) smooth	
Internal Diameter	6	inch
Length	550	ft
Elevation Change	0	ft
Fluid (65°F)	Air	
Compressed@	82.000049	psi a
Density	0.424063	lb/ft³
Viscosity	14.867712	Centistokes
Pressure Loss	17	psi
Flow Type	Turbulent	
Reynolds Number	3010501	
Friction Factor	0.009728	
Exit Velocity	217.854697	ft/sec
Exit Pressure	65.000049	psi a
Friction Loss	17.000000	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Entry Compressed	33.907548	ft³/sec
Exit Compressed	42.775670	ft³/sec
Mass Flow	14.378926	lb/sec
Standard Flow	16.440037	MMSCFD
CLOSE RESULTS		

Case 02: Gas Pipeline Flow Rate

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon Chapter 2, page 62 Example 13

Pipe Flow Wizard Software: Find_Flow_Case_02_Natural_Gas_Pipeline_Flow_Rate.pfwf

Calculation Problem:

Calculate the flow rate in a gas pipeline system, 15 miles long, with a 12.25 inch internal pipe diameter.

The upstream pressure is 1200 psi absolute and the delivery pressure required at the end of the pipe is 750 psi absolute. The pipe internal roughness is 700 micro-inches. Use a compressibility factor of 0.94 and a pipeline efficiency of 0.95.

The calculation methods used in the published data are:

- i) Weymouth equation
- ii) General Flow equation

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas specific gravity 0.59 (0.044 lb/ft³)
75 °F, 0.0 bar.g, Viscosity 0.0119 centipoise.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 700 micro-inches

Calculation Method: Weymouth equation (Efficiency = 0.95)
General Flow equation

Standard Atmospheric Conditions: 60°F, 14.696 psi.a

Gas Model: Real Gas (Ideal Gas Law, compressibility Z=0.94)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Comparing the result from the General Flow equation against the result from the Weymouth equation shows that the result from the Weymouth equation is quite conservative.

The screenshot shows the 'FindFlow' software interface with a 'Results' window open. The window displays various input and output parameters for a gas pipeline calculation. Key results include a pressure loss of 450 psi, a standard flow rate of 163.177644 MMSCFD (highlighted with an orange border), and other parameters like Reynolds number, friction factor, and exit velocity.

Parameter	Value	Units
Calc. Method	Weymouth Isothermal	
Efficiency	0.95	
Z Model	Custom Compressibility Factor	
Z =	0.94	
Material	Steel (ANSI) Sch. 20	
Internal Diameter	12.25	inch
Length	79200	ft
Elevation Change	0	ft
Fluid (75°F)	Natural Gas (SG = 0.59)	
Compressed@	1200	psi a
Density	3.804957	lb/ft ³
Viscosity	0.0119	Centipoise
Pressure Loss	450	psi
Flow Type	Turbulent	
Reynolds Number	13275724	
Friction Factor	0.011012	
Exit Velocity	43.729029	ft/sec
Exit Pressure	750.000000	psi a
Friction Loss	450.000000	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Entry Compressed	22.369147	ft ³ /sec
Exit Compressed	35.790634	ft ³ /sec
Mass Flow	85.113630	lb/sec
Standard Flow	163.177644	MMSCFD

At the bottom of the window is a button labeled 'CLOSE RESULTS'.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Gas Flow Rate, Weymouth equation, MMSCFD	163.26	163.178
Gas Flow Rate, General Flow equation, MMSCFD	192.98	192.984

Case 03: IGT (Institute of Gas Technology) Equation Flow Rate

Reference: Gas Pipeline Hydraulics, 2005, CRC Press, E. Shashi Menon, Chapter 2, page 71 Example 19

Pipe Flow Wizard Software: Find_Flow_Case_03_IGT_Equation.pfwf

Calculation Problem:

Find the flow rate in a natural gas pipeline 15 miles long.
 The pipe is NPS 16 with a 0.250 inch wall thickness.
 The inlet & outlet pressures are 1000 psi.g and 800 psi.g, respectively. The pipeline efficiency is 0.95.
 Average gas temperature is 80 °F.
 Gas Specific Gravity = 0.6, Viscosity = 0.000008 lb/ft-sec.
 The compressibility factor Z = 0.90

Use the IGT (Institute of Gas Technology) equation to calculate the flow rate in the pipe.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas with specific gravity 0.6 (0.044 lb/ft³), 80 °F, 0.00 psi.g, Viscosity 0.0119 centipoise.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 700 micro-inches.

Calculation Method: IGT Isothermal Flow equation.
Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Real Gas (Ideal Gas Law with compressibility Z=0.9)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Flow Rate MMSCFD	263.1	263.366

FindFlow

Results

Calc. Method: IGT Isothermal
 Efficiency: 0.95
 Z Model: Custom Compressibility Factor
 Z = 0.9
 Material: Steel (ANSI) Sch. 10
 Internal Diameter: 15.5 inch
 Length: 79200 ft
 Elevation Change: 0 ft
 Fluid (80°F): Natural Gas
 Compressed@: 1000 psi g
 Density: 3.37558 lb/ft³
 Viscosity: 0.0119 Centipoise
 Atmosphere: 14.695949 psi a
Pressure Loss: 200 psi

Flow Type: Turbulent
 Reynolds Number: 17169720
 Friction Factor: 0.010554
 Exit Velocity: 39.219393 ft/sec
 Pressure: psi g
 Entry Pressure: 1000.000000 psi g
 Exit Pressure: 800.000000 psi g
 Entry Density: 3.375580 lb/ft³
 Exit Density: 2.710242 lb/ft³
 Friction Loss: 200.000000 psi
 Fittings Loss: 0.000000 psi
 Elevation Loss: 0.000000 psi
 Entry Compressed: 41.262096 ft³/sec
 Exit Compressed: 51.391542 ft³/sec
 Mass Flow: 139.283521 lb/sec
Standard Flow: 263.366232 MMSCFD

CLOSE RESULTS

Case 04: Flow Rate of Natural Gas Through Pipeline

Reference: Gas Pipeline Hydraulics, 2013, CRC Press, E. Shashi Menon, Chapter 2, page 97 Example 2.20

Pipe Flow Wizard Software: Find_Flow_Case_04_Natural_Gas_Flow_Rate.pfwf

Calculation Problem:

A Natural gas pipeline, 24km long, is used to transport gas at an inlet pressure of 7000 kPa.g and an outlet pressure of 5500 kPa.g.

Calculate the flow rate using the IGT equation.
(IGT is Institute of Gas Technology)

Assume a pipeline efficiency of 0.95
and a compressibility factor Z of 0.9

Calculate the gas velocity at the inlet and outlet of the pipe.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Natural Gas at 20 °C, 0.0 bar.g
Gas with specific gravity of 0.6
Viscosity 0.00119 centipoise
Fluid Data: Software calculates compressed gas properties.
Pipe Data: DN 400 with 6mm wall thickness.

Calculation Method: IGT Isothermal Flow equation (Effic=0.95)
Standard Atmospheric Conditions: 15°C, 101.325 kPa.a
Gas Model: Real Gas (Ideal Gas Law with compressibility Z=0.9)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Flow Rate MMSCMD	7.67	7.640
Inlet Velocity (m/s)	9.78	9.771
Outlet Velocity (m/s)	12.4	12.387

FindFlow

Results

Calc. Method: IGT Isothermal
 Efficiency: 0.95
 Z Model: Custom Compressibility Factor
 Z = 0.9
 Material: Steel (ANSI) Sch. 40
 Internal Diameter: 388 mm
 Length: 24000 m
 Elevation Change: 0 m
 Fluid (20°C): Natural Gas
 Compressed@: 7000 kPa.g
 Density: 56.301318 kg/m³
 Viscosity: 0.0119 Centipoise
 Atmosphere: 101.325 kPa.a
Pressure Loss: 1500 kPa

Flow Type: Turbulent
 Reynolds Number: 17936380
 Friction Factor: 0.012460

Velocity

Entry Velocity: 9.770830 m/sec
 Exit Velocity: 12.387398 m/sec

Pressure

Entry Pressure: 7000.000000 kPa.g
 Exit Pressure: 5500.000000 kPa.g
 Entry Density: 56.301318 kg/m³
 Exit Density: 44.408893 kg/m³

Friction Loss: 1500.000000 kPa
 Fittings Loss: 0.000000 kPa
 Elevation Loss: 0.000000 kPa

Entry Compressed: 1.155273 m³/sec
 Exit Compressed: 1.464649 m³/sec
 Mass Flow: 65.043419 kg/sec
Standard Flow: 7.640249 MMSCMD

CLOSE RESULTS

Case 05: Pumping Hydrogen Gas from a Reservoir

Reference: Chemical Engineering Volume 1, 6th Ed, 1999, Elsevier, J M Coulson, J F Richardson, page 375 Example 8.10

Pipe Flow Wizard Software: Find_Flow_Case_05_Hydrogen_Reservoir_Pump.pfwf

Calculation Problem:

Hydrogen is pumped from a reservoir at 2 MN/m² through a clean horizontal mild steel pipe 50 mm in diameter and 500 m long. The pressure of the gas is raised to 2.5 MN/m² by a pump at the start of the pipe. The downstream pressure at the end of the pipe is 2 MN/m².

The conditions of flow are isothermal, and the temperature of the gas is 295 K.

What is the flow rate of hydrogen?

The calculation method used for the published data was the Complete Isothermal equation with Ideal Gas Law.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Hydrogen at 21.85 °C, 0.0 bar.g
Density 0.083279 kg/m³, Viscosity 0.008851 cP.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Internal diameter 50 mm, roughness 0.05 mm.

Calculation Method: Complete Isothermal Flow equation.
Standard Atmospheric Conditions: 20°C, 1.01325 bar absolute.
Gas Model: Ideal Gas Law

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The screenshot shows the 'FindFlow' software interface with a 'Results' window open. The window displays various calculated parameters for a hydrogen gas flow problem. The 'Calc. Method' is 'Complete Isothermal', and the 'Material' is 'Steel (ANSI) Sch. 40'. The 'Internal Diameter' is 50 mm, and the 'Length' is 500 m. The 'Fluid' is 'Hydrogen' at 21.85°C. The 'Compressed@' pressure is 2398.675 kPa g, and the 'Density' is 2.054750 kg/m³. The 'Viscosity' is 0.008851 Centipoise, and the 'Atmosphere' is 101.325 kPa a. The 'Pressure Loss' is 500 kPa. The 'Flow Type' is 'Turbulent', and the 'Reynolds Number' is 569547. The 'Friction Factor' is 0.018148. The 'Exit Velocity' is 61.334289 m/sec, and the 'Exit Pressure' is 1898.675000 kPa g. The 'Friction Loss' is 500.000000 kPa, 'Fittings Loss' is 0.000000 kPa, and 'Elevation Loss' is 0 kPa. The 'Entry Compressed' flow rate is 0.096344 m³/sec, and the 'Exit Compressed' flow rate is 0.120430 m³/sec. The 'Mass Flow' is 0.197962 kg/sec, and the 'Standard Flow' is 8503.877401 SCMH. The 'Mass Flow' value is highlighted with a red box.

Parameter	Value	Unit
Calc. Method	Complete Isothermal	
Material	Steel (ANSI) Sch. 40	
Internal Diameter	50	mm
Length	500	m
Elevation Change	0	m
Fluid (21.85°C)	Hydrogen	
Compressed@	2398.675	kPa g
Density	2.054750	kg/m ³
Viscosity	0.008851	Centipoise
Atmosphere	101.325	kPa a
Pressure Loss	500	kPa
Flow Type	Turbulent	
Reynolds Number	569547	
Friction Factor	0.018148	
Exit Velocity	61.334289	m/sec
Exit Pressure	1898.675000	kPa g
Friction Loss	500.000000	kPa
Fittings Loss	0.000000	kPa
Elevation Loss	0	kPa
Entry Compressed	0.096344	m ³ /sec
Exit Compressed	0.120430	m ³ /sec
Mass Flow	0.197962	kg/sec
Standard Flow	8503.877401	SCMH

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Flow Rate (kg/second)	0.200	0.198

Case 06: Carbon Dioxide – Flow Through a Pipe

Reference: 2500 Solved Problems in Fluid Mechanics and Hydraulics, 1989, McGraw-Hill, Jack B. Evett, Ph. D., Cheng Liu, M.S., Page 483, Example problem 16.78

Pipe Flow Wizard Software: Find_Flow_Case_06_Carbon_Dioxide_Flow_Through_A_Pipe.pfwf

Calculation Problem:

Carbon Dioxide at temperature of 100°F flows through a pipe with 6" internal diameter. The pipe internal roughness is 0.002 ft (0.024 inch). The flow is isothermal. The pressure at the start of a 120 ft long horizontal pipe section is 160 psi.g and the pressure at the end of the section is 150 psi.g.

Calculate the weight of flow (mass flow rate) of the air.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Carbon Dioxide at 155 psi gauge and 100 °F
Density 1.244000 lb/ft³, Viscosity 0.015500 centipoise.
The reference fluid properties can be defined for any pressure condition, however they must always be defined at the required temperature condition.

Fluid Data: The Pipe Flow Wizard software automatically calculates the compressed gas properties.

Pipe Data: Internal diameter 6 inch. Roughness 0.0024 inches.

Calculation Method: General Isothermal Flow equation.

Standard Atmospheric Conditions: 68 °F, 14.696 psi absolute

Gas Model: Ideal Gas Law

Commentary:

The published data and the calculated results compare well.

The published text assumes an initial Reynolds Number greater than 1000000 and a friction factor of 0.0285 to estimate the weight of flow as 25.3 lb/sec. The weight of flow is then used to recalculate the Reynolds Number as 5000000 and this is taken as confirmation of the previously calculated weight of flow.

The Pipe Flow Wizard software uses the Colebrook-White equation to calculate friction factors and these are generally considered to be more accurate than a value read from a Moody Chart.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Weight of Flow (lb/sec)	25.3	25.528
Reynolds Number	5000000	6241276
Friction Factor	0.0285	0.0284

The screenshot shows the 'FindFlow' software interface with the 'Results' window open. The window displays various input parameters and calculated results for a Carbon Dioxide flow problem. The 'Mass Flow' result is highlighted with a red box.

Parameter	Value	Units
Calc. Method	General Fundamental	
Material	Steel (ANSI) Galvanised Sch. 40	
Internal Diameter	6	inch
Length	120	ft
Elevation Change	0	ft
Fluid (100°F)	Carbon Dioxide	
Compressed@	160	psi g
Density	1.280654	lb/ft ³
Viscosity	0.77784	Centistokes
Atmosphere	14.695949	psi a
Pressure Loss	10	psi
Flow Type	Turbulent	
Reynolds Number	6241276	
Friction Factor	0.028400	
Exit Velocity	107.684321	ft/sec
Exit Pressure	150.000000	psi g
Friction Loss	10.000000	psi
Fittings Loss	0.000000	psi
Elevation Loss	0.000000	psi
Entry Compressed	19.933449	ft ³ /sec
Exit Compressed	21.143767	ft ³ /sec
Mass Flow	25.527847	lb/sec
Standard Flow	13404.458048	SCFM

At the bottom of the window is a button labeled 'CLOSE RESULTS'.

Find Diameter



Case 01: Minimum Pipe Diameter

Reference: Gas Pipeline Hydraulics, 2013
E. Shashi Menon, Ph. D., P.E, Pramila S. Menon, M. B. A., Chapter 3, page 128 Example 3.3

Pipe Flow Wizard Software: Find_Diameter_Case_01_Minimum_Pipe_Diameter.pfwd

Calculation Problem:

A pipeline 100 miles long transports natural gas, at a temperature of 60 °F. The inlet pressure is 1400 psi.g and the delivery pressure required is 800 psi.g. The required flowrate is 100 MMSCFD. Assume a compressibility factor of 0.9 and a 95% pipeline efficiency. The pipe roughness is 700 micro inches.

Find the minimum pipe diameter needed using the AGA, General with Colebrook-white, Panhandle B and Weymouth equations.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas Specific Gravity 0.6 (0.0458 lb/ft³)
Viscosity 0.0119 centipoise
@ 60 °F, 0.00 psi.g
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Internal roughness 0.000700 inches.

Calculation Method: AGA equation
General Flow equation
Panhandle B equation
Weymouth equation

Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Real Gas (Ideal Gas Law with compressibility Z=0.90)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Colebrook-white refers to the method used to calculate friction factors in the General Isothermal Flow equation.

FindDiameter

Results

Calc. Method: General Fundamental

Material: Steel (ANSI) Sch. 20

Length: 528000 ft

Elevation Change: 0 ft

Fluid (60°F): Natural Gas (SG = 0.60)

Compressed@: 1400 psi.g

Density: 4.898786 lb/ft³

Viscosity: 0.0119 Centipoise

Atmosphere: 14.695949 psi.a

Standard Flow: 100 MMSCFD

Mass Flow: 53.009269 lb/sec

Compressed Flow: 10.8209 ft³/sec

Pressure Loss: 600 psi

Flow Type: Turbulent

Reynolds Number: 8078414

Friction Factor: 0.011103

Exit Velocity: 21.916024 ft/sec

Exit Pressure: 800.000000 psi.g

Exit Flow Compressed: 18.790180 ft³/sec

Friction Loss: 600.000000 psi

Fittings Loss: 0.000000 psi

Elevation Loss: 0.000000 psi

Diameter: 12.537787 inch

CLOSE RESULTS

Results Comparison:

Data Item	Published Data	Equation	Pipe Flow Wizard
Pipe Diameter	12.47 inches	AGA	12.461 inches
Pipe Diameter	12.55 inches	General	12.538 inches
Pipe Diameter	11.93 inches	Panhandle B	11.930 inches
Pipe Diameter	13.30 inches	Weymouth	13.304 inches

Case 02: Natural Gas Flow Rate vs Pressure Drop In Steel Pipe

Reference: Fluid Flow Handbook, 2002, McGraw-Hill, Jamal M. Saleh, Ph D., PE, Chapter 9, page 9.14 Ex. 9.5.1

Pipe Flow Wizard Software: Find_Diameter_Case_02_Diameter_of_Pipeline_78_miles_long.pfwd

Calculation Problem:

Find the inside diameter of a steel pipe used to transport natural gas (SG = 0.87) a distance of 78 miles when the following requirements are specified.

The inlet pressure is 600 psi.g and the maximum allowable pressure drop is 145 psi.g.

Assume isothermal flow, a pipeline efficiency of 0.92, and a compressibility factor $Z = 0.8337$ (calculated from Papay's correlation).

The calculation method used for the published data was the Panhandle B equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Natural Gas at 70 °F, 0.0 psi.g
Density 0.650 lb/ft³, Viscosity 0.0119 centipoise
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Internal diameter 18.812 inches (nominal 20")
Roughness 0.001811 inches (Steel Schedule 40)

Calculation Method: Panhandle B Isothermal equation.

Standard Atmospheric Conditions: 60°F, 14.696 psi.a

Gas Model: Real Gas (Ideal Gas Law & compressibility $Z=0.8337$)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Internal Diameter	18.80 inches	18.794 inches

FindDiameter

Results

Calc. Method	Panhandle B Isothermal
Efficiency	0.92
Z Model	Custom Compressibility Factor
Z =	0.8337
Material	Steel (ANSI) Sch. 40
Length	411840 ft
Elevation Change	0.000000 ft
Fluid (70°F)	Natural Gas (SG = 0.87)
Compressed@	600 psi.g
Density	3.270598 lb/ft ³
Viscosity	0.0119 Centipoise
Atmosphere	14.695949 psi.a
Standard Flow	100 MMSCFD
Mass Flow	76.902134 lb/sec
Compressed Flow	23.513169 ft ³ /sec
Pressure Loss	145 psi
Flow Type	Turbulent
Reynolds Number	7818310
Friction Factor	0.012131
Exit Velocity	15.972979 ft/sec
Exit Pressure	455.000000 psi.g
Exit Flow Compressed	30.771927 ft ³ /sec
Friction Loss	145.000000 psi
Fittings Loss	0.000000 psi
Elevation Loss	0.000000 psi
Diameter	18.794063 inch

CLOSE RESULTS

Case 03: Diameter of an Air Pipeline

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, P.E., Page 288, Example 5.17

Pipe Flow Wizard Software: Find_Diameter_Case_03_Diameter_of_Air_Pipeline.pfwd

Calculation Problem:

A pipeline 20,000 ft in length allows air at 4000 SCFM.
The initial pressure is 150 psi.a.

If the pressure drop is limited to 50 psi, determine the approximate pipe diameter required.

The calculation method used for the published data was the Weymouth equation.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 60 °F, 0.0 psi.g
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 0.001811 inches (Steel Schedule 40)

Calculation Method: Weymouth Isothermal Flow equation.
Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Internal Diameter	6.53 inches	6.531 inches

FindDiameter

Results

Calc. Method: Weymouth Isothermal
 Efficiency: 1
 Z Model: Ideal Gas Law
 Z = 1
 Material: Steel (ANSI) Sch. 40
 Length: 20000 ft
 Elevation Change: 0 ft
 Fluid (60°F): Air
 Compressed@: 135.304051 psi.g
 Density: 0.778898 lb/ft³
 Viscosity: 0.017988 Centipoise
 Atmosphere: 14.695949 psi.a
Standard Flow: 4000 SCFM
Mass Flow: 5.087401 lb/sec
Compressed Flow: 6.531534 ft³/sec
Pressure Loss: 50 psi

Flow Type: Turbulent
 Reynolds Number: 984687
 Friction Factor: 0.015459
 Exit Velocity: 42.117776 ft/sec
 Exit Pressure: 85.304051 psi.g
 Exit Flow Compressed: 9.797301 ft³/sec
 Friction Loss: 50.000000 psi
 Fittings Loss: 0.000000 psi
 Elevation Loss: 0.000000 psi
Diameter: 6.530656 inch

CLOSE RESULTS

Case 04: Designing a Free Air Pipeline

Reference: Piping Calculations Manual, 2005, McGraw-Hill, E. Shashi Menon, P.E., Page 281, Example 5.15

Pipe Flow Wizard Software: Find_Diameter_Case_04_Free_Air_Pipeline.pfwd

Calculation Problem:

A pipe is to be designed to carry 150CFM free air at 100 psi.g and 80°F.

If the pressure loss must be limited to 5 psi per 100 ft of pipe, what is the minimum pipe diameter required?

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Free Air at 80 °F, 100 psi.g
Density 0.574 lb/ft³, Viscosity 0.017141 centipoise.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 0.0018 inches

Calculation Method: General Isothermal Flow Equation.
Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The published example guesses an internal diameter and then proceeds to check if this meets the pressure drop restriction, iterating to an approximate solution.

The problem specifies that the pressure loss must be limited to a value of 5 psi per 100 ft and so a pressure drop of 5 psi was used in the Pipe Flow Wizard software to calculate the exact answer.

The screenshot shows the 'FindDiameter' software interface. The 'Results' window is open, displaying various calculation parameters and results. The 'Calc. Method' is set to 'General Fundamental'. The 'Z Model' is 'Ideal Gas Law'. The 'Z' factor is 1. The 'Material' is 'Steel (ANSI) Sch. 40'. The 'Length' is 100 ft. The 'Elevation Change' is 0 ft. The 'Fluid (80°F)' is 'Air'. The 'Compressed@' is 100 psi.g. The 'Density' is 0.574 lb/ft³. The 'Viscosity' is 0.017141 Centipoise. The 'Atmosphere' is 14.695949 psi.a. The 'Standard Flow' is 150 SCFM. The 'Mass Flow' is 0.190942 lb/sec. The 'Compressed Flow' is 0.332652 ft³/sec. The 'Pressure Loss' is 5 psi. The 'Flow Type' is 'Turbulent'. The 'Reynolds Number' is 239744. The 'Friction Factor' is 0.023268. The 'Exit Velocity' is 57.134453 ft/sec. The 'Exit Pressure' is 95.000000 psi.g. The 'Exit Flow Compressed' is 0.347815 ft³/sec. The 'Friction Loss' is 5.000000 psi. The 'Fittings Loss' is 0.000000 psi. The 'Elevation Loss' is 0.000000 psi. The 'Diameter' is 1.056480 inch. A 'CLOSE RESULTS' button is at the bottom.

Results Comparison:

Data Item	Published data	Pipe Flow Wizard
Inner Diameter	1.049 inches	1.056 inches
Pressure Drop (per 100ft)	5.05 psi	5.00 psi

Find Length



Case 01: Length of a Wrought Iron Pipe

Reference: Fluid Mechanics and Hydraulics, 3rd Ed, 1994, Schaums, McGraw-Hill;
R. V. Giles, J. B. Evett PhD, C. Liu, page 155, Example 8.25

Pipe Flow Wizard Software: Find_length_Case_01_Wrought_Iron_Pipe_Length.pfwl

Calculation Problem:

A horizontal wrought iron pipe of 150 mm internal diameter is transporting 20 N of air per second (2.0394 kg/s) from A to B.

At A the pressure is 483 kPa absolute, and at B the pressure must be 448 KPa absolute.

What is the length of pipe from A to B?

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 20°C, 0.0 kPa.g
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 0.0004 m (0.4 mm)

Calculation method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 20 °C, 101.325 KPa.a
Gas Model: Ideal Gas Law.

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

This example gives a friction factor as read from a diagram; Pipe Flow Wizard gives the friction factor to more decimal places.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Length	173 m	171.25 m
Reynolds Number	968000	961736
Friction Factor	0.025	0.02545

The screenshot shows the 'FindLength' software interface. The 'Results' window is open, displaying various calculated parameters. The 'Calc. Method' is set to 'General Fundamental' and the 'Z Model' is 'Ideal Gas Law'. The 'Material' is 'Wrought Iron' with a 'Schedule / Class' of 'Class A'. The 'Internal Diameter' is 150 mm. The 'Fluid' is 'Air' at 20°C. The 'Compressed@' pressure is 483 kPa.a. The 'Mass Flow' is 2.039432 kg/sec. The 'Standard Flow' is 6097.970681 SCM/H. The 'Compressed Flow' is 0.355347 m³/sec. The 'Pressure Loss' is 0.35 bar. The 'Flow Type' is 'Turbulent'. The 'Reynolds Number' is 961736. The 'Friction Factor' is 0.025450. The 'Exit Velocity' is 21.679488 m/sec. The 'Entry Pressure' is 483.000000 kPa.a and the 'Exit Pressure' is 448.000000 kPa.a. The 'Entry Density' is 5.739275 kg/m³ and the 'Exit Density' is 5.323385 kg/m³. The 'Flow' section shows 'Entry Compressed' as 0.355347 m³/sec, 'Exit Compressed' as 0.383108 m³/sec, 'Mass Flow' as 2.039432 kg/sec, and 'Standard Flow' as 6097.970681 SCM/H. The 'Friction Loss' is 0.350000 bar, 'Fittings Loss' is 0.000000 bar, and 'Elevation Loss' is 0 bar. The 'Length' is 171.252391 m. A 'CLOSE RESULTS' button is at the bottom.

Calc. Method	General Fundamental
Z Model	Ideal Gas Law
Z =	1
Material	Wrought Iron
Schedule / Class	Class A
Internal Roughness	0.4 mm
Nominal Size	150 mm
Internal Diameter	150 mm
Elevation Change	0.000000 m
Fluid (20°C)	Air
Compressed@	483 kPa.a
Density	5.739275 kg/m³
Viscosity	0.018 Centipoise
Mass Flow	2.039432 kg/sec
Standard Flow	6097.970681 SCM/H
Compressed Flow	0.355347 m³/sec
Pressure Loss	0.35 bar
Flow Type	Turbulent
Reynolds Number	961736
Friction Factor	0.025450
Exit Velocity	21.679488 m/sec
Pressure	
Entry Pressure	483.000000 kPa.a
Exit Pressure	448.000000 kPa.a
Entry Density	5.739275 kg/m³
Exit Density	5.323385 kg/m³
Flow	
Entry Compressed	0.355347 m³/sec
Exit Compressed	0.383108 m³/sec
Mass Flow	2.039432 kg/sec
Standard Flow	6097.970681 SCM/H
Friction Loss	0.350000 bar
Fittings Loss	0.000000 bar
Elevation Loss	0 bar
Length	171.252391 m

Case 02: Compressor Stations for a Gas Transmission Pipeline

Reference: Gas Pipeline Hydraulics (paperback), 2013
E. Shashi Menon, Ph. D., P.E, Pramila S. Menon, M. B. A., Chapter 3, page 208 Example 4.11

Pipe Flow Wizard Software: Find_length_Case_02_Gas_Compressor_Stations.pfwl

Calculation Problem:

A gas transmission, NPS 30 pipeline, has a compressor station that will be placed in the line before delivering the gas to a final location downstream named Douglas. The inlet flow rate of 900 MMSCFD equals the delivery flow rate at Douglas. The delivery pressure required is 600 psi.g and the MOP (Maximum Operating Pressure) of the pipeline is 1400 psi.g throughout.

Neglect the effects of elevation and assume a constant gas flow temperature of 80 °F, a constant transmission factor $F=20$, and a compressibility factor $Z = 0.85$ throughout the pipeline.

Find the maximum distance (in miles) from Douglas that the compressor station at 1400 psi.g can be located.

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Gas Specific Gravity of 0.6, 80 °F, 0.0 psi.g
Fluid Data: Software calculates compressed gas properties.
Pipe Data: NPS 30, 0.5 inch wall thickness.
Internal roughness 0.00100 inches.

Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Real Gas (Custom Compressibility Factor $Z=0.85$)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

The example specifies a transmission factor, $F=20$, and in order to achieve this value, we set the internal roughness of the pipe to be 0.001 inch.

Note: Transmission Factor $F = \frac{2}{\sqrt{f}}$ where f is the friction factor.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Length (miles)	112.31	111.996

The screenshot shows the 'FindLength' software interface with the 'Results' window open. The 'Calc. Method' is set to 'General Fundamental'. The 'Z Model' is 'Custom Compressibility Factor' with $Z = 0.85$. The 'Material' is 'Steel (ANSI)' with 'Schedule / Class' 'Sch. 40'. The 'Internal Roughness' is 0.001 inch, 'Nominal Size' is 32 inch, and 'Internal Diameter' is 29 inch. The 'Elevation Change' is 0 ft. The 'Fluid (80°F)' is 'Natural Gas (SG = 0.60)'. The 'Compressed@' pressure is 1400 psi.g, with 'Density' 4.998059 lb/ft³, 'Viscosity' 0.012 Centipoise, and 'Atmosphere' 14.7 psi.a. The 'Standard Flow' is 900 MMSCFD, 'Mass Flow' is 477.400743 lb/sec, 'Compressed Flow' is 95.517226 ft³/sec, and 'Pressure Loss' is 800 psi. The 'Flow Type' is 'Turbulent', 'Reynolds Number' is 31192199, 'Friction Factor' is 0.010015, 'Exit Velocity' is 47.924706 ft/sec. The 'Pressure' section shows 'Entry Pressure' 1400.000000 psi.g, 'Exit Pressure' 600.000000 psi.g, 'Entry Density' 4.998059 lb/ft³, and 'Exit Density' 2.171702 lb/ft³. The 'Flow' section shows 'Entry Compressed' 95.517226 ft³/sec, 'Exit Compressed' 219.827915 ft³/sec, 'Mass Flow' 477.400743 lb/sec, and 'Standard Flow' 900 MMSCFD. The 'Friction Loss' is 800.000000 psi, 'Fittings Loss' is 0.000000 psi, and 'Elevation Loss' is 0 psi. The 'Length' is 591666.649089 ft. A 'CLOSE RESULTS' button is at the bottom.

Calc. Method	General Fundamental
Z Model	Custom Compressibility Factor
Z =	0.85
Material	Steel (ANSI)
Schedule / Class	Sch. 40
Internal Roughness	0.001 inch
Nominal Size	32 inch
Internal Diameter	29 inch
Elevation Change	0 ft
Fluid (80°F)	Natural Gas (SG = 0.60)
Compressed@	1400 psi.g
Density	4.998059 lb/ft³
Viscosity	0.012 Centipoise
Atmosphere	14.7 psi.a
Standard Flow	900 MMSCFD
Mass Flow	477.400743 lb/sec
Compressed Flow	95.517226 ft³/sec
Pressure Loss	800 psi
Flow Type	Turbulent
Reynolds Number	31192199
Friction Factor	0.010015
Exit Velocity	47.924706 ft/sec
Pressure	
Entry Pressure	1400.000000 psi.g
Exit Pressure	600.000000 psi.g
Entry Density	4.998059 lb/ft³
Exit Density	2.171702 lb/ft³
Flow	
Entry Compressed	95.517226 ft³/sec
Exit Compressed	219.827915 ft³/sec
Mass Flow	477.400743 lb/sec
Standard Flow	900 MMSCFD
Friction Loss	800.000000 psi
Fittings Loss	0.000000 psi
Elevation Loss	0 psi
Length	591666.649089 ft

Case 03: Length of Steel Air Pipe

Reference: Flow of Fluids – Technical Paper No 410, 1988, Crane Co. Page B-15.

Pipe Flow Wizard Software: Find_Length_Case_03_Air_Steel_Pipe.pfwl

Calculation Problem:

Air compressed at 100 psi.g flows through a nominal 5 inch schedule 40 steel pipe at a flow rate of 1300 SCFM.

If the pressure drop in the pipe is 0.103 lbs/inch² (psi), what is the length of pipe?

Pipe Flow Wizard Software Calculation Data:

Fluid Ref: Air at 60°F, 0.0 psi.g.
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Steel (ANSI) Sch.40
 Roughness 0.001811 inches

Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 60°F, 14.696 psi.a
Gas Model: Ideal Gas Model (Compressibility Z=1.00)

Commentary:

See the Results Comparison Table below.

The published data and the calculated results compare well.

Results Comparison:

Data Item	Published Data	Pipe Flow Wizard
Length (ft)	100	99.66

The screenshot shows the 'FindLength' software interface. The 'Results' window is open, displaying various calculation parameters and results. The 'Calc. Method' is set to 'General Fundamental' and the 'Z Model' is 'Ideal Gas Law'. The 'Material' is 'Steel (ANSI)' with a 'Schedule / Class' of 'Sch. 40'. The 'Internal Roughness' is 0.001811 inch, 'Nominal Size' is 5 inch, and 'Internal Diameter' is 5.047 inch. The 'Elevation Change' is 0 ft. The 'Fluid (60°F)' is 'Air'. The 'Compressed@' pressure is 100 psi.g, with 'Density' of 0.595577 lb/ft³ and 'Viscosity' of 0.017988 Centipoise. The 'Atmosphere' is 14.695949 psi.a. The 'Standard Flow' is 1300 SCFM, 'Mass Flow' is 1.653405 lb/sec, and 'Compressed Flow' is 2.776142 ft³/sec. The 'Pressure Loss' is 0.103 psi. The 'Flow Type' is 'Turbulent', 'Reynolds Number' is 414100, and 'Friction Factor' is 0.016921. The 'Exit Velocity' is 20.000365 ft/sec and 'Exit Pressure' is 99.897000 psi.g. The 'Flow' section shows 'Entry Compressed' (2.776142 ft³/sec), 'Exit Compressed' (2.778638 ft³/sec), 'Mass Flow' (1.653405 lb/sec), and 'Standard Flow' (1300.000000 SCFM). The 'Friction Loss' is 0.103000 psi, 'Fittings Loss' is 0.000000 psi, and 'Elevation Loss' is 0.000000 psi. The 'Length' is calculated as 99.656300 ft. A 'CLOSE RESULTS' button is at the bottom.

Calc. Method	General Fundamental
Z Model	Ideal Gas Law
Z =	1
Material	Steel (ANSI)
Schedule / Class	Sch. 40
Internal Roughness	0.001811 inch
Nominal Size	5 inch
Internal Diameter	5.047 inch
Elevation Change	0 ft
Fluid (60°F)	Air
Compressed@	100 psi.g
Density	0.595577 lb/ft ³
Viscosity	0.017988 Centipoise
Atmosphere	14.695949 psi.a
Standard Flow	1300 SCFM
Mass Flow	1.653405 lb/sec
Compressed Flow	2.776142 ft ³ /sec
Pressure Loss	0.103 psi
Flow Type	Turbulent
Reynolds Number	414100
Friction Factor	0.016921
Exit Velocity	20.000365 ft/sec
Exit Pressure	99.897000 psi.g
Flow	
Entry Compressed	2.776142 ft ³ /sec
Exit Compressed	2.778638 ft ³ /sec
Mass Flow	1.653405 lb/sec
Standard Flow	1300.000000 SCFM
Friction Loss	0.103000 psi
Fittings Loss	0.000000 psi
Elevation Loss	0.000000 psi
Length	99.656300 ft

CLOSE RESULTS

References

1. Fluid Mechanics and Hydraulics, 3rd Ed, 1994, McGraw-Hill
R. V. Giles, J. B. Evett PhD, C. Liu
2. Gas Pipeline Hydraulics, 2005 Hardback, CRC Press
E. Shashi Menon
3. Gas Pipeline Hydraulics, 2013, CRC Press
E. Shashi Menon
4. Chemical Engineering Volume 1, 6th Ed, 1999, Elsevier
J M Coulson, J F Richardson
5. Flow of Fluids through Valves, Fittings and Pipe Metric Edition – SI Units, Crane Technical Paper 410M,
Crane Ltd.
6. Elementary Fluid Mechanics, 1940, John Wiley & Sons, Inc., John K. Vennard
7. Fluid Flow Handbook, 2002, McGraw-Hill
Jamal M. Saleh, Ph D., PE
8. Piping Calculations Manual, 2005, McGraw-Hill
E. Shashi Menon
9. 2500 Solved Problems in Fluid Mechanics and Hydraulics, 1989, McGraw-Hill
Jack B. Evett Ph. D., Cheng Liu M.S.