pipeflow®

taking the pressure out of fluid flow calculations

gas pressure drop

Verification of Calculation Results

For Compressible Flow

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Table of Contents – Results Data: Systems Solved by Gas Pressure Drop

Introduction

Pipe Flow Gas Pressure Drop is a software application that calculates the pressure drop for gas flow in a pipe. Friction losses are calculated using specialist compressible isothermal flow equations. 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, gas flow rate, pressure at the start of the pipe, and gas density at the entry condition.

The gas pressure drop calculations produced by the Pipe Flow Gas Pressure Drop 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 **App 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 Gas Pressure Drop 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 Gas Pressure Drop 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 Gas Pressure Drop software calculates an accurate friction factor using the Colebrook-White equation.

In addition to the **General Flow Equation**, Pipe Flow Gas Pressure Drop 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 Pipe Flow Gas 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: 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

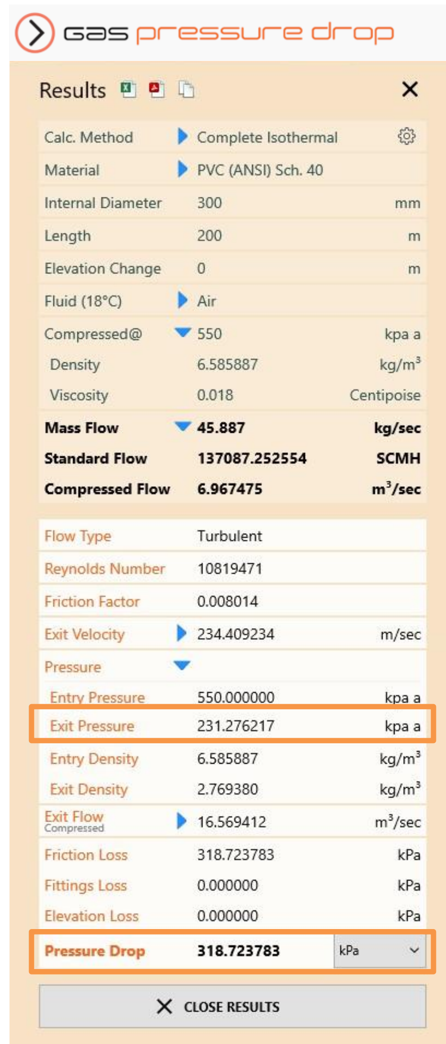
Gas Pressure Drop App: Find_Pressure_Case_01_Air_Pipeline_Pressure_Loss.pfwp

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 Gas Pressure Drop 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. Kg/s = (kN/s) x (1000/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 Gas Pressure Drop calculation.

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	Gas Pressure Drop
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

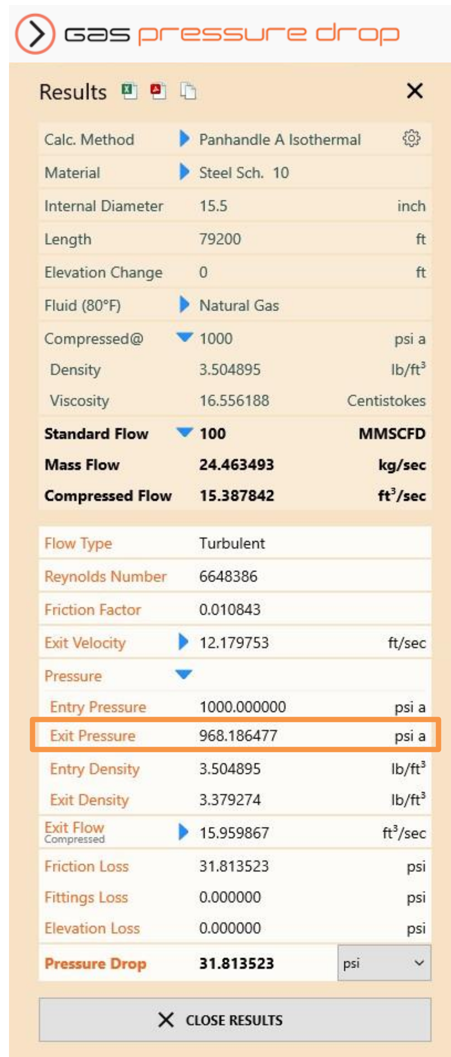
Gas Pressure Drop App: Find_Pressure_Case_02_Natural_Gas_Pipeline_Outlet_Pressure.pfwp

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 Gas Pressure Drop 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	App
Outlet Pressure (psi absolute)	968.35	968.19
Pressure Drop (psi)	31.65	31.81

Case 03: Gas Pipeline Inlet Pressure

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

Gas Pressure Drop App: 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 Mm^3/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 Gas Pressure Drop Software Calculation Data:

Fluid Ref: Gas Specific Gravity 0.6 (0.723 kg/m^3)
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 Mm^3/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.

Results Comparison:

Data Item	Published Data	App
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

Gas Pressure Drop App: Find_Pressure_Case_04_Methane_Compressor_Flow_Rate.pfwp

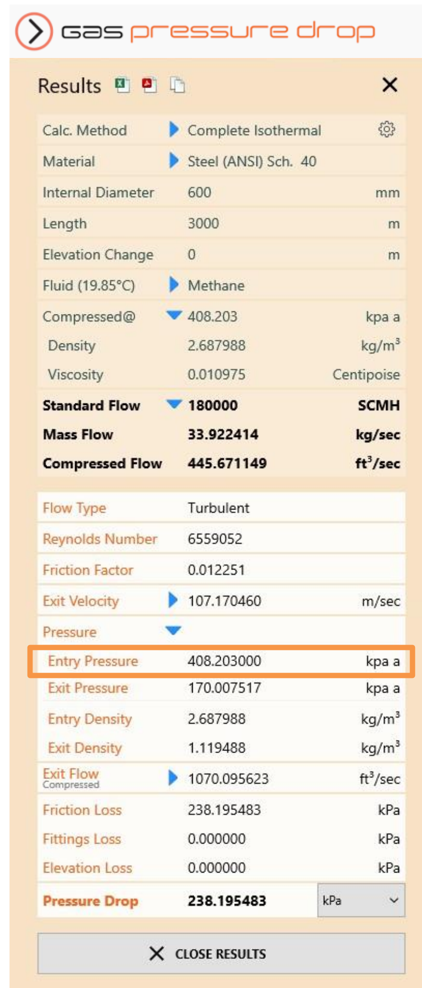
Calculation Problem:

A flow of 50 m^3/s (180000 m^3/h) of methane, starting at a temperature of 288 K and 101.3 kN/m^2 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/m^2 (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 Gas Pressure Drop Software Calculation Data:

Fluid Ref: Methane at 293 K average, 0.00 kPa.g, Density 0.667218 kg/m^3 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.

Results Comparison:

Data Item	Published Data	App
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.

Gas Pressure Drop App: 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 Mm^3/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 Gas Pressure Drop Software Calculation Data:

Fluid Ref: Natural Gas
Specific Gravity 0.65 (0.783 kg/m^3)
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	App
Inlet pressure (MPa absolute)	5.077	5.07795
Pressure Drop (MPa)	1.077	1.07795
Delivery Pressure (MPa)	4.0	4.0

Case 06: Gas Pipeline Outlet Pressure vs Length

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

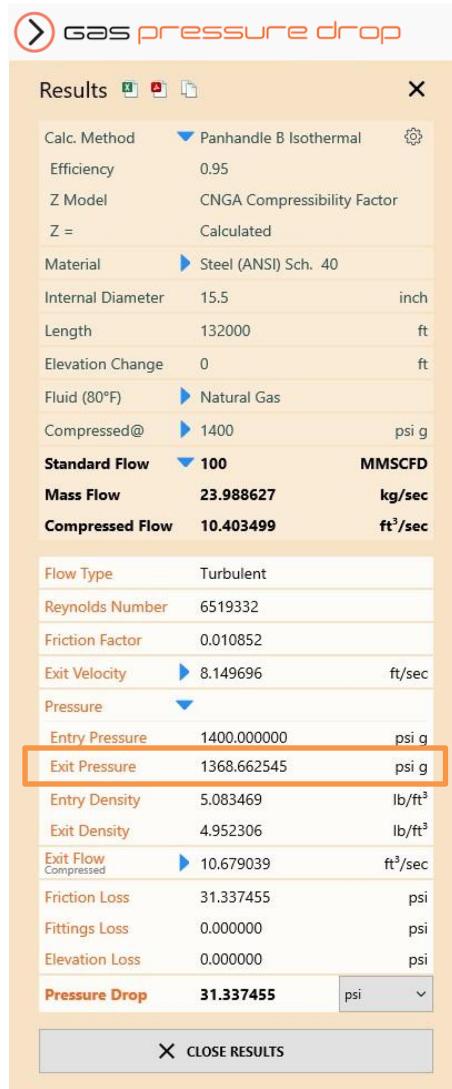
Gas Pressure Drop App: Find_Pressure_Case_06_Outlet_Pressure_vs_Length.pfwp

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 Gas Pressure Drop 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 Gas Pressure Drop 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.

Result Comparison:

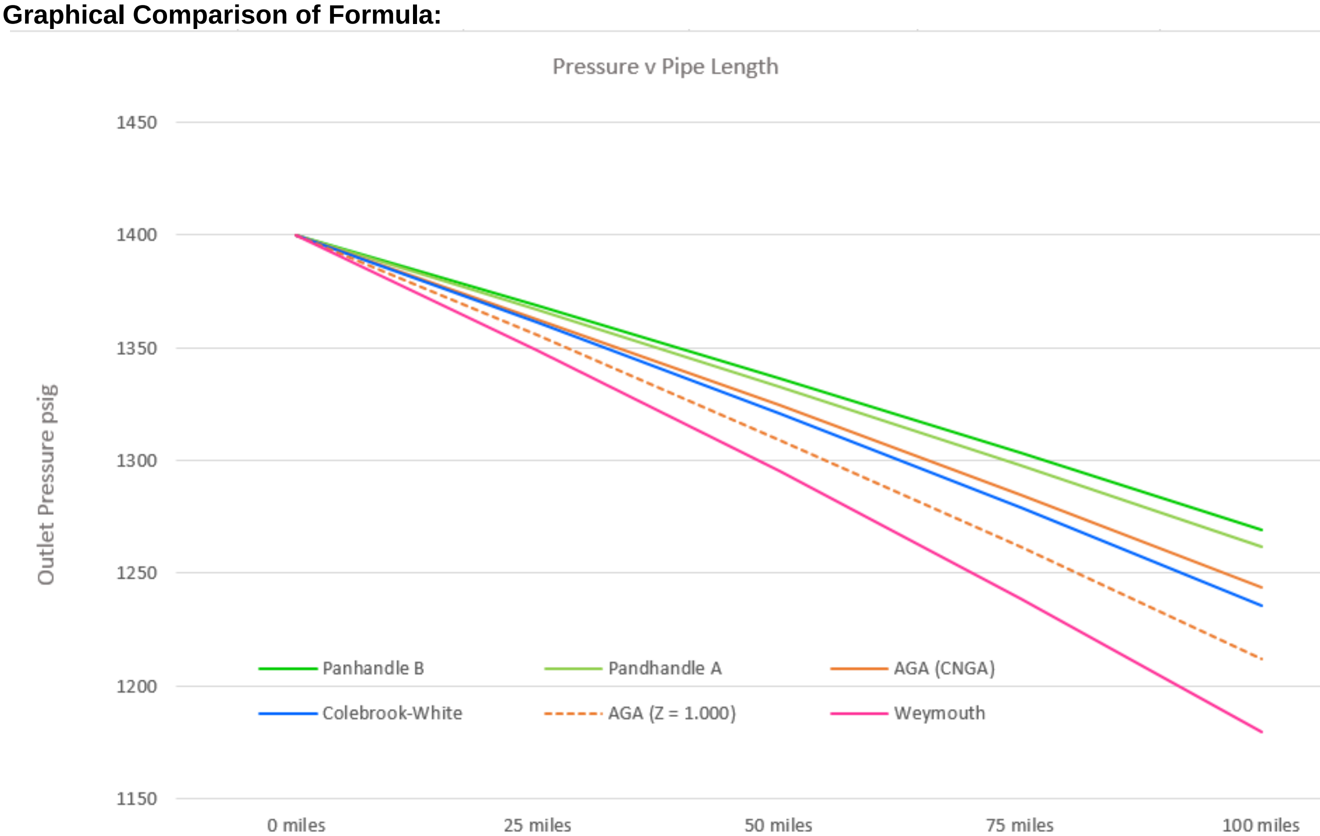
Published Graph Readings of Outlet Pressures (Psi.g):

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 Gas Pressure Drop 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

Gas Pressure Drop App: 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 Gas Pressure Drop 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 Gas Pressure Drop software automatically calculated the same CNGA 0.8662 compressibility factor.

Results Comparison:

Data Item	Published Data	App
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

Gas Pressure Drop App: 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 Gas Pressure Drop Software Calculation Data:

Fluid Ref: Air at 80 °F, 0.0 psi.g
Density 0.0736 lb/ft^3, 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 Gas Pressure Drop 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	App
Outlet Pressure (psi.a)	94.18	94.178
Pressure Drop (psi)	20.52	20.518

Case 09: Air Flowing through Horizontal Pipe

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

Gas Pressure Drop App: 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*(V2/V1) since this is normally small compared to f*(L/D).

Pipe Flow Gas Pressure Drop Software Calculation Data:

Fluid Ref: Air at 100 °F, 0.0 psi.g
Density 0.071 lb/ft^3, 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 Gas Pressure Drop software used a pipe roughness of 0.000001 inches, calculating a friction factor of 0.014818.

Results Comparison:

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

Case 10: Gas Pipeline Inlet Pressure vs Flow Rate

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

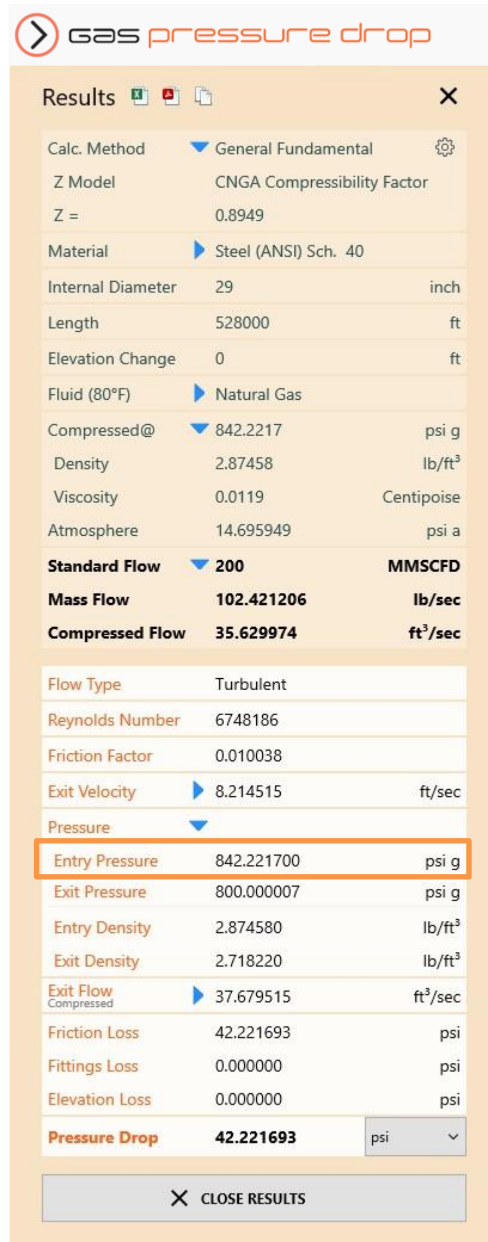
Gas Pressure Drop App: Find_Pressure_Case_10_Inlet_Pressure_vs_Flow_Rate.pfwp

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 Gas Pressure Drop Software Calculation Data:

Fluid Ref: Gas specific gravity 0.6 at 80 °F, 0.00 psi.g, Density 0.044 lb/ft^3, 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 Gas Pressure Drop 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.

Results Comparison:

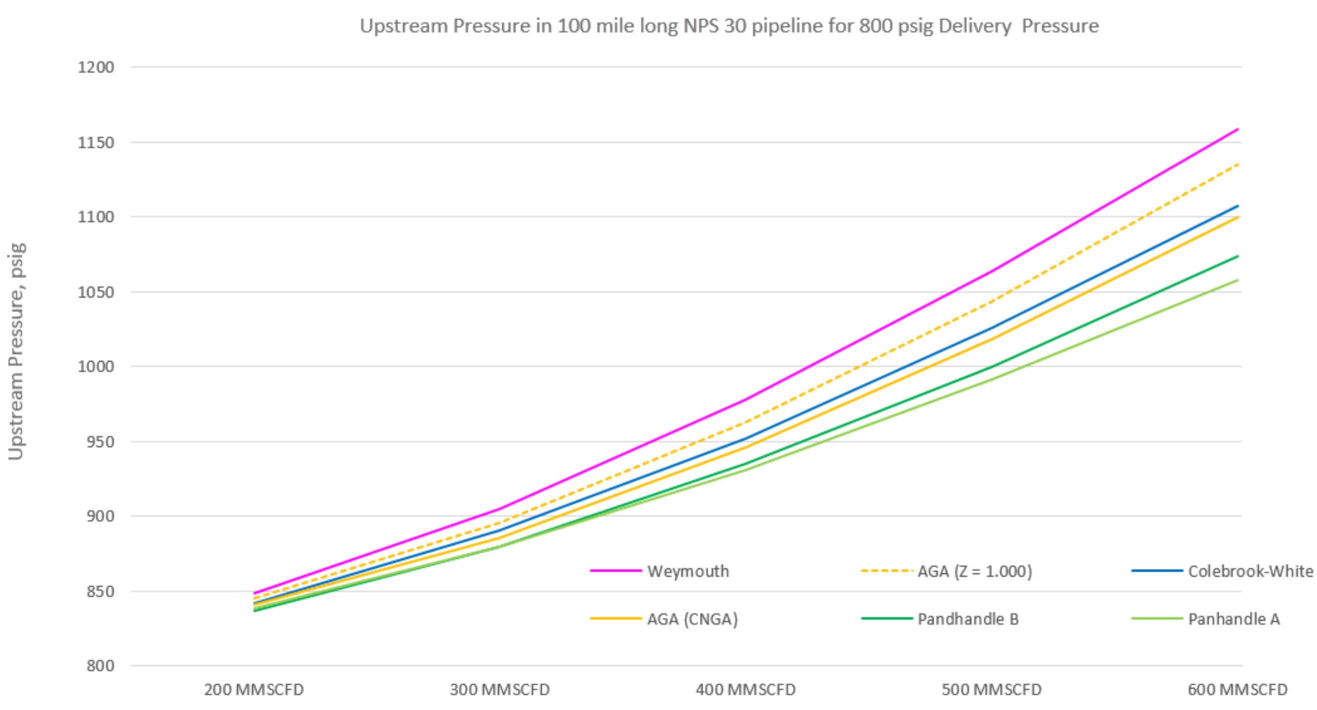
Published Graph Readings of Inlet Pressures (Psi.g):

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 Gas Pressure Drop 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

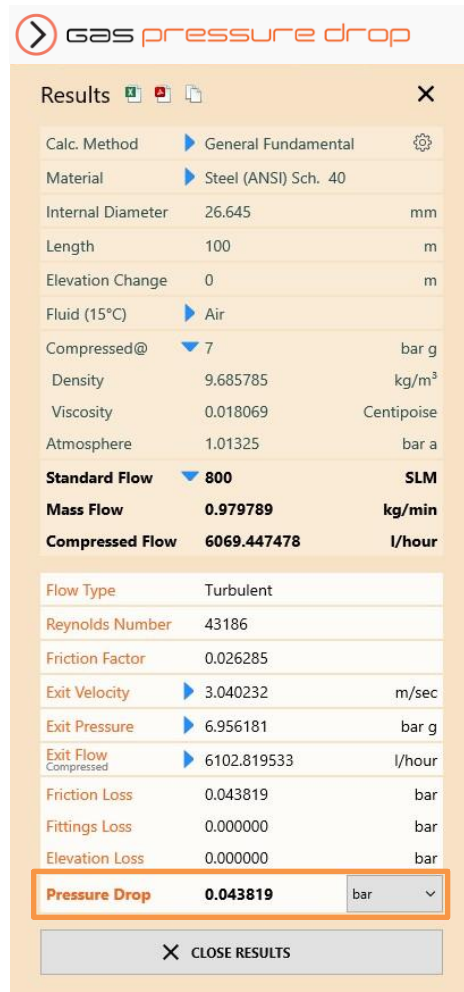
Reference: Flow of Fluids – Technical Paper No 410M, 1999, Crane Co. Appendix B-14.

Gas Pressure Drop App: 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 Gas Pressure Drop 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 results produced using a non-compressible calculation equation give almost the same figures), whereas the Pipe Flow Gas Pressure Drop 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).

Results Comparison:

Pipe Details Steel Schedule 40	Free Air m³/min	Compressed Flow m³/min	Published Pressure Drop (Bar)	App 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.

Gas Pressure Drop App: 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 Gas Pressure Drop 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.

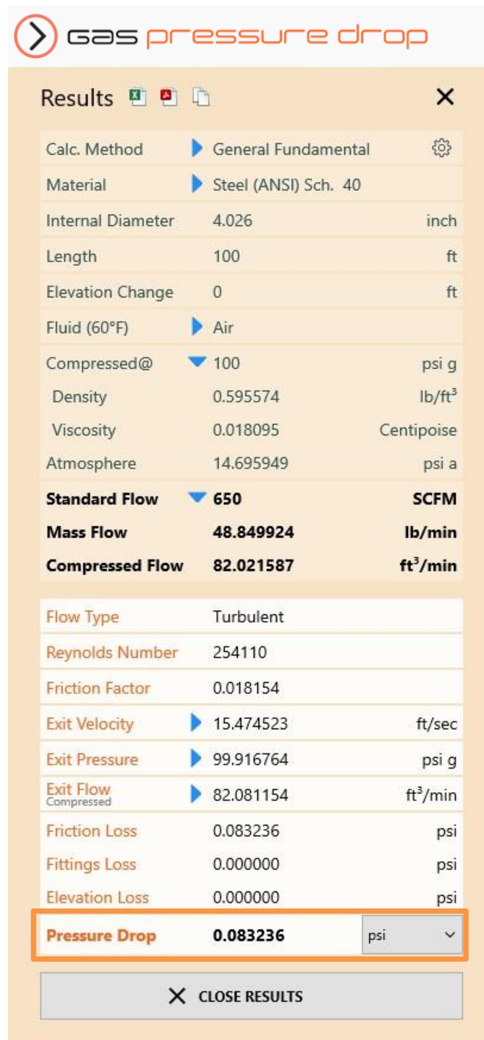
Calculation Method: General Isothermal Flow equation.
Standard Atmospheric Conditions: 60 °F, 14.696 psi absolute
Gas Model: Ideal Gas Law

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 Gas Pressure Drop 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.



Results Comparison:

Pipe Details Steel Schedule 40	Free Air ft³/min	Compressed Flow ft³/min	Published Data Pressure Drop (psi)	App 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

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