pipeFLOW®

taking the pressure out of fluid flow calculations

gas

pipe diameter

Verification of Calculation Results For Compressible Flow

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Introduction

Pipe Flow Gas Pipe Diameter is a software application that calculates the minimum size of pipe diameter that allows a given gas flow rate within a specified pressure drop. Friction losses are calculated using specialist compressible isothermal flow equations. The pressure loss in the pipe is affected by items such as the internal roughness of the pipe material, internal pipe diameter size, pipe length, gas flow rate, pressure at the start of the pipe, and gas density at the entry condition.

The gas pipe diameter calculations produced by the Pipe Flow Gas Pipe Diameter 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 diameter sizes.

For each of the calculation problems detailed in this document, the results data produced by the **Pipe Flow Gas Pipe Diameter 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 Pipe Diameter 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 Pipe Diameter software calculates an accurate friction factor using the Colebrook-White equation.

In addition to the **General Flow Equation**, Pipe Flow Gas Pipe Diameter 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 Pipe Diameter 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: Minimum Pipe Diameter

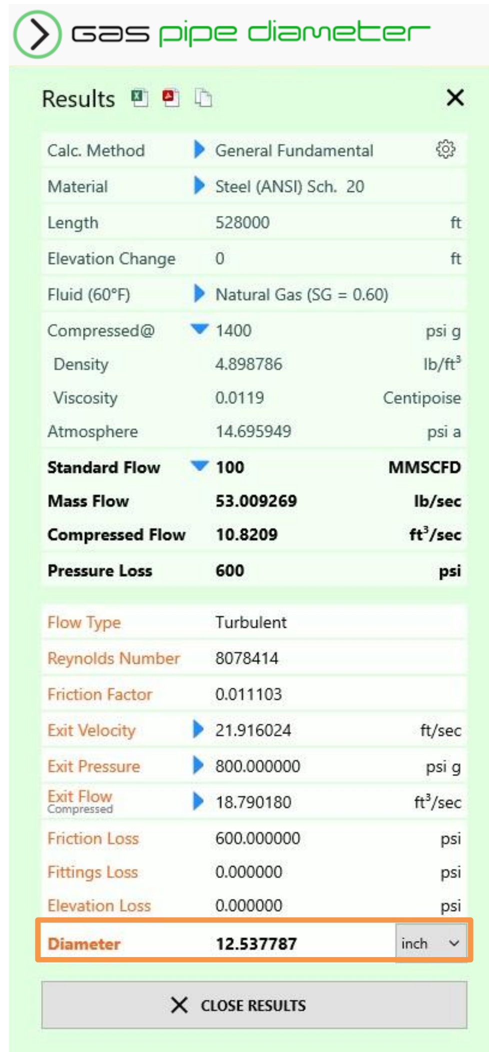
Reference: Gas Pipeline Hydraulics, 2013
E. Shashi Menon, Ph. D., P.E, Pramila S. Menon, M. B. A., Chapter 3, page 128 Example 3.3

Gas Pipe Diameter App: Find_Diameter_Case_01_Minumum_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 Gas Pipe Diameter 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.

Results Comparison:

Data Item	Published Data	Equation	App
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

Gas Pipe Diameter App: Find_Diameter_Case_02_Diameter_of_Pipeline_78_miles_long.pfwd

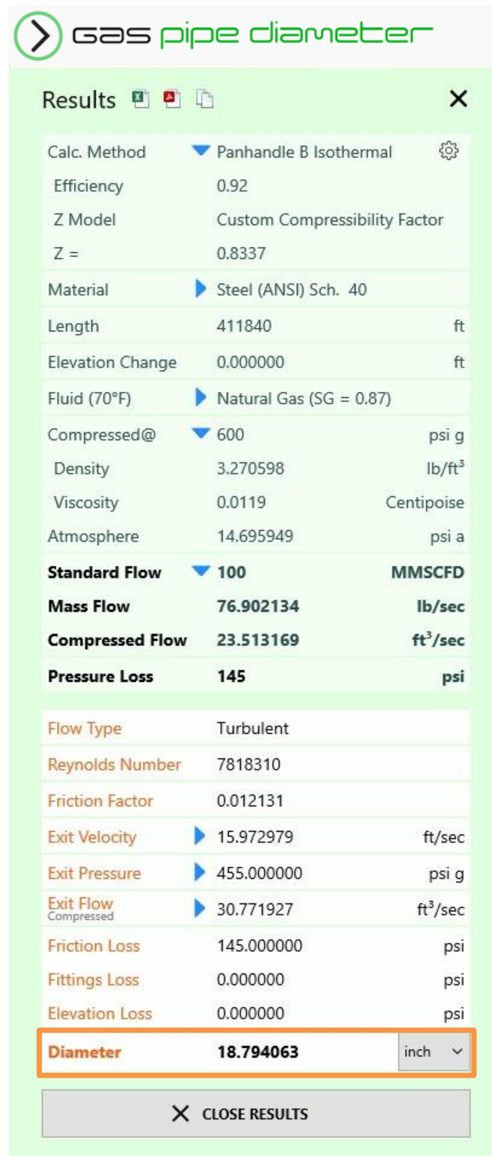
Calculation Problem:

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 Gas Pipe Diameter Software Calculation Data:

Fluid Ref: Natural Gas at 70 °F, 0.0 psi.g
Density 0.650 lb/ft^3, 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	App
Internal Diameter	18.80 inches	18.794 inches

Case 03: Diameter of an Air Pipeline

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

Gas Pipe Diameter App: 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 Gas Pipe Diameter Software Calculation Data:

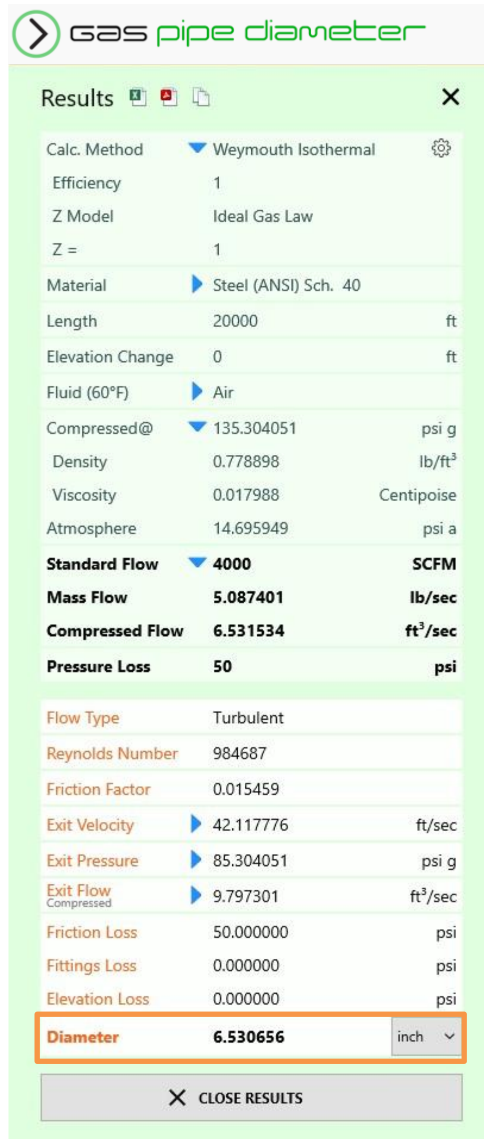
Fluid Ref: Air at 60 °F, 0.0 psi.g
Fluid Data: Software calculates compressed gas properties.
Pipe Data: Roughness 0.001811 inches (Steel Schedule 40)

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	App
Internal Diameter	6.53 inches	6.531 inches

Case 04: Designing a Free Air Pipeline

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

Gas Pipe Diameter App: 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 Gas Pipe Diameter Software Calculation Data:

Fluid Ref: Free Air at 80 °F, 100 psi.g
Density 0.574 lb/ft^3, 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.

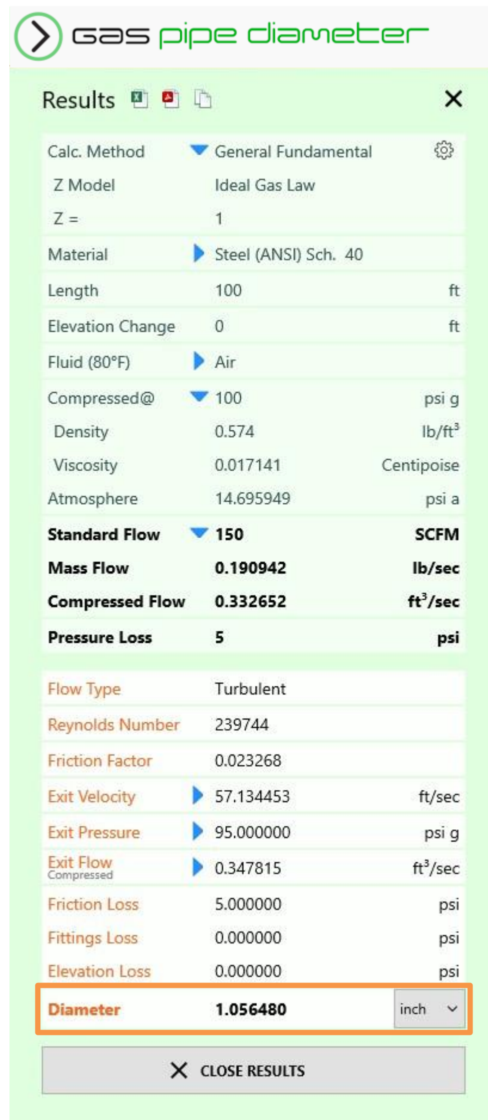
Commentary:

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 Gas Pipe Diameter software to calculate the exact answer.



Results Comparison:

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

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