

Pipeline Toolbox Function Reference Manual

DD-00011-000

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1 About this Guide

1.1 Legal Information

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2 Overview

2.1 Introduction

The *Adelsbach Pipeline Toolbox* is a function library for MATLAB and GNU Octave, providing functionality for engineers in the pipeline construction industry.

The goal of the *Adelsbach Pipeline Toolbox* is to provide an extensive function library to solve various numerical calculations pipeline engineers will encounter during the development and realization of a pipeline project.

3 Reference

3.1 Unit Conversions

3.1.1 bblh_galh - bbl/h to gal/h $y = \text{bblh_galh}(x)$

Converts oil barrels per hour (bbl/h) to gallons per hour (gal/h).

Arguments

x Value in oil barrels per hour (bbl/h).

Returns Value in gallons per hour (gal/h).

3.1.2 galh_bblh - gal/h to bbl/h $y = \text{galh_bblh}(x)$

Converts gallons per hour (gal/h) to oil barrels per hour (bbl/h).

Arguments

x Value in gallons per hour (gal/h).

Returns Value in oil barrels per hour (bbl/h).

3.1.3 bblh_m3h - bbl/h to m³/h $y = \text{bblh_m3h}(x)$

Converts oil barrels per hour (bbl/h) to cubic metres per hour (m³/h).

Arguments

x Value in oil barrels per hour (bbl/h).

Returns Value in cubic metres per hour (m³/h).

3.1.4 m3h_bblh - m³/h to bbl/h $y = \text{m3h_bblh}(x)$

Converts cubic metres per hour (m³/h) to oil barrels per hour (bbl/h).

Arguments

x Value in cubic metres per hour (m³/h).

Returns Value in oil barrels per hour (bbl/h).

3.1.5 galh_m3h - gal/h to m³/h $y = \text{galh_m3h}(x)$

Converts gallons per hour (gal/h) to cubic metres per hour (m³/h).

Arguments

x Value in gallons per hour (gal/h).

Returns Value in cubic metres per hour (m³/h).

3.1.6 m3h_galh - m³/h to gal/h $y = \text{m3h_galh}(x)$

Converts cubic metres per hour (m³/h) to gallons per hour (gal/h).

Arguments

x Value in cubic metres per hour (m³/h).

Returns Value in gallons per hour (gal/h).

3.1.7 psi_kpa - psi to kPa $y = \text{psi_kpa}(x)$

Converts pound per square inch (psi) to kilopascals (kPa).

Arguments

x Value in pound per square inch (psi).

Returns Value in kilopascals kPa.

3.1.8 kpa_psi - kPa to psi $y = \text{kpa_psi}(x)$

Converts kilopascals (kPa) to pound per square inch (psi).

Arguments

x Value in kilopascals (kPa).

Returns Value in pound per square inch psi.

3.1.9 psimi_kpakm - psi/mi to kPa/km $y = \text{psimi_kpakm}(x)$

Converts pound per square inch per mile (psi/mi) to kilopascals per kilometer (kPa/km).

Arguments

x Value in pound per square inch per mile (psi/mi).

Returns Value in kilopascals per kilometer kPa/km.

3.1.10 kpakm_psimi - kPa/km to psi/mi $y = \text{kpakm_psimi}(x)$

Converts kilopascals per kilometer (kPa/km) to pound per square inch per mile (psi/mi).

Arguments

x Value in kilopascals per kilometer (kPa/km).

Returns Value in pound per square inch per mile psi/mi.

3.1.11 lbh_kgh - lb/h to kg/h $y = \text{lbh_kgh}(x)$

Converts pounds per hour (lb/h) to kilograms per hour (kg/h).

Arguments

x Value in pounds per hour (lb/h).

Returns Value in kilograms per hour (kg/h).

3.1.12 kgh_lbh - kg/h to lb/h $y = \text{kgh_lbh}(x)$

Converts kilograms per hour (kg/h) to pounds per hour (lb/h).

Arguments

x Value in kilograms per hour (kg/h).

Returns Value in pounds per hour (lb/h).

3.1.13 ft3lb_m3kg - ft³/lb to m³/kg

y = ft3lb_m3kg(x)

Converts cubic feet per pound (ft³/lb) to cubic metres per kilogram (m³/kg).

Arguments

x Value in cubic feet per pound (ft³/lb).

Returns Value in cubic metres per kilogram (m³/kg).

3.1.14 m3kg_ft3lb - m³/kg to ft³/lb $y = \text{m3kg_ft3lb}(x)$

Converts cubic metres per kilogram (m³/kg) to cubic feet per pound (ft³/lb).

Arguments

x Value in cubic metres per kilogram (m³/kg).

Returns Value in cubic feet per pound (ft³/lb).

3.2 Darcy friction factor calculation

3.2.1 colebrook_white - Colebrook-White equation

```
f = colebrook_white(d,e,re,coeff='normal')
```

Calculate the Colebrook-White equation for a given Reynolds number Re , a pipe diameter D and an absolute roughness ϵ .

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{\epsilon}{3.7D} + \frac{c}{Re\sqrt{f}} \right)$$

The equation is solved numerically. If the D argument is not needed it can be set to $D = 1$. The constant c nominally is $c = 2.51$, however the American Gas Association (AGA) and the American Bureau of Mines recommend $c = 2.825$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ϵ .

re Reynolds number

coeff Optional coefficient to use, this can be:

normal Standard definition of $c = 2.51$ (*default*).

aga or abm Definition of $c = 2.825$.

(numeric value) Real number, user supplied.

Returns Darcy friction factor f , dimensionless.

Possible Warnings

Colebrook-White formula is for turbulent flow $Re > 4000$ The Colebrook-White equation is normally for turbulent flow.

Possible Errors

Colebrook-white vectors must be of same size Multiple arguments are specified as vectors whose number of elements don't match.

Colebrook-White unknown coefficient string type The given `coeff` argument is not numeric, but also not one of *normal*, *abm* or *aga*.

3.2.2 cw_haaland - Haaland friction factor

`f = cw_haaland(d,e,re)`

Calculate the Haaland approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Haaland diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.3 cw_swamee_jain - Swamee-Jain friction factor

`f = cw_swamee_jain(d,e,re)`

Calculate the Swamee-Jain approximation of the Colebrook-White equation for flow in the region of $5000 \leq Re \leq 10^8$ as well as $1e-6 \leq \epsilon/D \leq 0.05$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ϵ .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Swamee-Jain is only valid for $5000 \leq Re \leq 1e8$ The given Reynolds number is out of range.

Swamee-Jain is only valid for $1e-6 \leq \epsilon/D \leq 0.05$ The given pipe roughness/diameter fraction is out of range.

Swamee-Jain diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.4 cw_serghides - Serghides friction factor

`f = cw_serghides(d,e,re)`

Calculate the Serghides approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Serghides diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.5 cw_goudar_sonnad1 - Goudar-Sonnad (2006) friction factor $f = \text{cw_goudar_sonnad1}(d, e, re)$

Calculate the Goudar-Sonnad approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Goudar-Sonnad-1 diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.6 cw_goudar_sonnad2 - Goudar-Sonnad (2011) friction factor $f = \text{cw_goudar_sonnad2}(d, e, re)$

Calculate the Goudar-Sonnad approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Goudar-Sonnad-2 diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.7 cw_brkic - Brkic friction factor

$f = \text{cw_brkic}(d, e, re)$

Calculate the Brkic approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Brkic diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.8 cw_brkic_praks - Brkic-Praks friction factor

$f = \text{cw_brkic_praks}(d, e, re)$

Calculate the Brkic-Praks approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Brkic-Praks diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.9 cw_praks_brkic - Praks-Brkic friction factor

$f = \text{cw_praks_brkic}(d, e, re)$

Calculate the Praks-Brkic approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Praks-Brkic diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.10 cw_niazkar - Niazkar friction factor

$f = \text{cw_niazkar}(d, e, re)$

Calculate the Niazkar approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Niazkar diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.11 cw_moody - Moody friction factor

$f = \text{cw_moody}(d, e, \text{re})$

Calculate the Moody approximation of the Colebrook-White equation in range $4000 \leq \text{Re} \leq 5 \times 10^8$ and $0 \leq \varepsilon/D \leq 0.01$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Moody approximation only valid within $4000 \leq \text{Re} \leq 5e8$ The given Reynolds number is out of range.

Moody approximation only valid within $0 \leq \varepsilon/D \leq 0.01$ The given pipe roughness/diameter fraction is out of range.

Moody diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.12 `cw_wood` - Wood friction factor $f = cw_wood(d, e, re)$

Calculate the Wood approximation of the Colebrook-White equation in range $4000 \leq Re \leq 5 \times 10^7$ and $1 \times 10^{-5} \leq \epsilon/D \leq 0.04$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ϵ .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Wood approximation only valid within $4000 \leq Re \leq 5e7$ The given Reynolds number is out of range.

Wood approximation only valid within $1e-5 \leq e/D \leq 0.04$ The given pipe roughness/diameter fraction is out of range.

Wood diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.13 cw_eck - Eck friction factor $f = \text{cw_eck}(d, e, re)$

Calculate the Eck approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Eck diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.14 cw_churchill1 - Churchill (1973) friction factor $f = \text{cw_churchill1}(d, e, re)$

Calculate the Churchill approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Churchill-1 diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.15 cw_churchill12 - Churchill (1977) friction factor $f = \text{cw_churchill12}(d, e, re)$

Calculate the Churchill approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Churchill-2 diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.16 cw_jain - Jain friction factor

$f = \text{cw_jain}(d, e, re)$

Calculate the Jain approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Jain diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.17 cw_chen - **Chen friction factor**

f = cw_chen(d,e,re)

Calculate the Chen approximation of the Colebrook-White equation for $4000 \leq Re \leq 4 \times 10^8$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Chen friction approximation only valid for $4000 \leq Re \leq 4e8$ The given Reynolds number is out of range.

Chen diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.18 cw_round - Round friction factor $f = \text{cw_round}(d, e, re)$

Calculate the Round approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Round diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.19 cw_barr - Barr friction factor

$f = \text{cw_barr}(d, e, re)$

Calculate the Barr approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Barr diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.20 cw_zigrang_sylvester1 - Zigrang-Sylvester friction factor

$f = \text{cw_zigrang_sylvester1}(d, e, re)$

Calculate the Zigrang-Sylvester, single recursion approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Zigrang-Sylvester-1 diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.21 cw_zigrang_sylvester2 - Zigrang-Sylvester friction factor

$f = \text{cw_zigrang_sylvester2}(d, e, re)$

Calculate the Zigrang-Sylvester, double recursion approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Zigrang-Sylvester-2 diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.22 cw_tsal - Tsal friction factor

$f = \text{cw_tsal}(d, e, re)$

Calculate the Tsal approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Tsal diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.23 cw_manadilli - Manadilli friction factor

$f = \text{cw_manadilli}(d, e, \text{re})$

Calculate the Manadilli approximation of the Colebrook-White equation for range $4000 \leq \text{Re} \leq 10^8$ and $0 \leq \varepsilon/D \leq 0.05$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Manadilli approximation is only valid for $4000 \leq \text{Re} \leq 1e8$ The given Reynolds number is out of range.

Manadilli approximation is only valid for $0 \leq \varepsilon/D \leq 0.05$ The given pipe roughness/diameter fraction is out of range.

Manadilli diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.24 cw_romeo_royo_monzon - Romeo-Royo-Monzon friction factor $f = \text{cw_romeo_royo_monzon}(d, e, re)$

Calculate the Romeo-Royo-Monzon approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Romeo-Royo-Monzon diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.25 cw_vatankhah_kouchakzadeh - **Vatankhah-Kouchakzadeh friction factor**

$f = \text{cw_vatankhah_kouchakzadeh}(d, e, re)$

Calculate the Vatankhah-Kouchakzadeh approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Vatankhah-Kouchakzadeh diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.26 cw_buzzelli - Buzzelli friction factor

$f = \text{cw_buzzelli}(d, e, re)$

Calculate the Buzzelli approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Buzzelli diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.27 cw_cheng - Cheng friction factor $f = \text{cw_cheng}(d, e, re)$

Calculate the Cheng approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Cheng diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.28 cw_avci_kargoz - **Avci-Kargoz friction factor** $f = \text{cw_avci_kargoz}(d, e, re)$

Calculate the Avci-Kargoz approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Avci-Kargoz diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.29 `cw_evangelides` - **Evangelides-Papaevangelou-Tzimopoulos friction factor**

`f = cw_evangelides(d,e,re)`

Calculate the Evangelides-Papaevangelou-Tzimopoulos approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Evangelides diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.30 cw_fang - Fang friction factor $f = \text{cw_fang}(d, e, re)$

Calculate the Fang approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Fang diameter is <= 0 The given internal diameter of the pipe must be above zero.

3.2.31 cw_alashkar - Alashkar friction factor $f = \text{cw_alashkar}(d, e, re)$

Calculate the Alashkar approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Alashkar diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.32 cw_bellos - Bellos-Nalbantis-Tsakiris friction factor

$f = \text{cw_bellos}(d, e, re)$

Calculate the Bellos-Nalbantis-Tsakiris approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Bellos diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.33 cw_tkachenko1 - Tkachenko-Mileikovskiy friction factor

$f = \text{cw_tkachenko1}(d, e, re)$

Calculate the Tkachenko-Mileikovskiy approximation of the Colebrook-White equation valid for $2320 \leq Re \leq 10^9$ and $0 \leq e/D \leq 0.65$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Tkachenko-1 is only valid for $2320 \leq Re \leq 1e9$ The given Reynolds number is out of range.

Tkachenko-1 is only valid for $0 \leq e/D \leq 0.65$ The given pipe roughness/diameter fraction is out of range.

Tkachenko-1 diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.34 cw_tkachenko2 - Tkachenko-Mileikovskiy friction factor

$f = \text{cw_tkachenko2}(d, e, re)$

Calculate the Tkachenko-Mileikovskiy approximation of the Colebrook-White equation valid for $2320 \leq Re \leq 10^9$ and $0 \leq e/D \leq 0.65$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Tkachenko-2 is only valid for $2320 \leq Re \leq 1e9$ The given Reynolds number is out of range.

Tkachenko-2 is only valid for $0 \leq e/D \leq 0.65$ The given pipe roughness/diameter fraction is out of range.

Tkachenko-2 diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.35 cw_blasius - Blasius friction factor

f = cw_blasius(re)

Calculate the Blasius approximation of the Colebrook-White equation.

Arguments

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Blasius friction factor only valid for $2100 < \text{Re} < 1e5$ The given Reynolds number is out of range.

Blasius diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.36 cw_koo - **Koo friction factor** $f = \text{cw_koo}(\text{re})$

Calculate the Koo approximation of the Colebrook-White equation.

Arguments

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Koo friction factor only valid for $1e4 < \text{Re} < 1e7$ The given Reynolds number is out of range.

Koo diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.2.37 cw_nikuradse_reichert - **Nikuradse-Reichert friction factor**

`f = cw_nikuradse_reichert(d,e,re)`

Calculate the Nikuradse-Reichert approximation of the Colebrook-White equation.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε .

re Reynolds number

Returns Darcy friction factor f , dimensionless.

Possible Errors

Nikuradse-Reichert friction factor only valid for $Re > 1e4$ The given Reynolds number is out of range.

Nikuradse-Reichert friction factor only valid for $e/D > 0.01$ The given pipe roughness/diameter fraction is out of range.

Nikuradse-Reichert diameter is ≤ 0 The given internal diameter of the pipe must be above zero.

3.3 Helical Pipes

3.3.1 dean_number - Dean number De

de = dean_number(re,d,r,p=undefined)

Computes the *Dean number* De given the Reynolds number Re, the helix radius R_H and the pipe internal diameter D . The Dean number is then defined as:

$$De = Re \sqrt{\frac{D}{2R_H}}$$

Optionally the pitch of the helix P can be specified, in which case the following more complete definition of the Dean number will be used:

$$De = Re \sqrt{\frac{d}{2R_H \left(1 + \left(\frac{P}{2\pi R_H} \right)^2 \right)}}$$

Arguments

re Reynolds number Re.

d Pipe internal diameter D (m).

r Helix radius R_H (m).

p Helix pitch P .

Returns Dean number De, dimensionless.

Possible Errors

Dean-Number unknown amount of arguments Unknown amount of arguments supplied.

Dean-Number some given helical radius is <= 0 The given helical radius or any of the vector elements, if it is a vector are below or equal to zero.

Dean-Number some given pipe diameter is <= 0 The given pipe diameter or any of the vector elements, if it is a vector are below or equal to zero.

3.3.2 `germano_number` - **Germano number** G_n

`gn = germano_number(re,r,p,cr)`

Computes the *Germano number* G_n given the Reynolds number Re , the helical pitch P , radius R_H and the curvature ratio C_r . The Germano number is then defined as:

$$G_n = \frac{Re C_r^2 P / 2\pi R_H}{1 + (C_r P / 2\pi R_H)^2}$$

Arguments

re Reynolds number Re .

r Helix radius R_H (m).

p Helix pitch p (m).

cr Curvature ratio (dimensionless)

Returns Germano number G_n , dimensionless.

Possible Errors

Germano-Number unknown amount of arguments Unknown amount of arguments supplied.

Germano-Number some given helical radius is ≤ 0 The given helical radius or any of the vector elements, if it is a vector are below or equal to zero.

Germano-Number some given helical pitch is ≤ 0 The given helical pitch or any of the vector elements, if it is a vector are below or equal to zero.

3.3.3 helical_white - White helical friction factor

`f = helical_white(re, de)`

Computes the White friction factor for helical pipes with a given dean number in range of $11.6 \leq De \leq 2000$.

Arguments

re Reynolds number Re .

de Dean number De .

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Warnings

Helical-White friction only valid for $11.6 \leq De \leq 2000$ The White helical pipe friction factor is only valid for a $11.6 \leq De \leq 2000$.

Possible Errors

Helical-White unknown amount of arguments An unknown amount of arguments was specified.

3.3.4 helical_hart - Hart helical friction factor

f = helical_hart(re, de)

Computes the Hart friction factor for helical pipes with a given dean number valid for the entire laminar flow region.

Arguments

re Reynolds number Re.

de Dean number De.

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Errors

Helical-Hart unknown amount of arguments An unknown amount of arguments was specified.

3.3.5 helical_gnielinski - Gnielinski helical friction factor

`f = helical_gnielinski(re,de,d,r)`

Computes the Gnielinski friction factor for helical pipes for turbulent flow.

Arguments

re Reynolds number Re .

de Dean number De .

d Pipe inner diameter (m).

r Helix radius R .

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Errors

Helical-Gnielinski unknown amount of arguments An unknown amount of arguments was specified.

3.3.6 helical_mishra_gupta - Mishra-Gupta friction factor

`f = helical_mishra_gupta(re, de)`

Computes the Mishra-Gupta friction factor for helical pipes with a given dean number valid for the entire laminar flow region.

Arguments

re Reynolds number Re .

de Dean number De .

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Warnings

Helical-Mishra-Gupta friction only valid for $1 \leq De \leq 3000$ The White helical pipe friction factor is only valid for a $1 \leq De \leq 3000$.

Possible Errors

Helical-Mishra-Gupta unknown amount of arguments An unknown amount of arguments was specified.

3.3.7 helical_mori_nakayama - Mori-Nakayama friction factor

f = helical_mori_nakayama(re, de)

Computes the Mori-Nakayama friction factor for helical pipes with a given dean number valid for the entire laminar flow region.

Arguments

re Reynolds number Re.

de Dean number De.

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Errors

Helical-Mori-Nakayama unknown amount of arguments An unknown amount of arguments was specified.

3.3.8 helical_srinivasan - Srinivasan friction factor

f = helical_srinivasan(re, de)

Computes the Srinivasan et al. friction factor for helical pipes with a given dean number valid for the entire laminar flow region.

Arguments

re Reynolds number Re.

de Dean number De.

Returns Helical friction factor (Darcy definition) f_H , dimensionless.

Possible Errors

Helical-Srinicasan unknwon amount of arguments An unknown amount of arguments was specified.

3.4 Compressibility

3.4.1 hall_yarborough - Hall-Yarborough equation of state

`z = hall_yarborough(ppr, tpr)`

Computes the compressibility factor Z using the Hall-Yarborough method using the pseudo-reduced pressure and temperature.

Arguments

ppr Pseudo-reduced pressure P_{pr} .

tpr Pseudo-reduced temperature T_{pr} .

Returns Compressibility factor Z .

Possible Errors

Hall-Yarborough unknown amount of arguments The given number of arguments is unknown.

Hall-Yarborough model only valid for Tpr >= 1 The Hall-Yarborough equation requires that $T_{pr} \geq 1$.

3.4.2 dranchuk_purvis_robinson - Dranchuk-Purvis-Robinson equation of state

```
z = dranchuk_purvis_robinson(ppr, tpr)
```

Computes the compressibility factor Z using the Dranchuk-Purvis-Robinson method using the pseudo-reduced pressure and temperature.

Arguments

ppr Pseudo-reduced pressure P_{pr} .

tpr Pseudo-reduced temperature T_{pr} .

Returns Compressibility factor Z .

Possible Errors

Dranchuk-Purvis-Robinson unknown amount of arguments The given number of arguments is unknown.

3.4.3 dranchuck_abou_kassem - Dranchuk & Abou-Kassem equation of state

`z = dranchuck_abou_kassem(ppr, tpr)`

Computes the compressibility factor Z using the Dranchuk & Abou-Kassem method using the pseudo-reduced pressure and temperature.

Please note that this equation can be numerically unstable and as such results should be verified.

Arguments

ppr Pseudo-reduced pressure P_{pr} .

tpr Pseudo-reduced temperature T_{pr} .

Returns Compressibility factor Z .

Possible Errors

Dranchuk-Abou-Kassem unknown amount of arguments The given number of arguments is unknown.

Dranchuk-Abou-Kassem converged improperly The resulting compressibility factor is not plausible.

3.4.4 `beggs_brill` - **Beggs-Brill equation of state**

`z = beggs_brill(ppr, tpr)`

Computes the compressibility factor Z using the Beggs-Brill method using the pseudo-reduced pressure and temperature.

Arguments

ppr Pseudo-reduced pressure P_{pr} .

tpr Pseudo-reduced temperature T_{pr} .

Returns Compressibility factor Z .

Possible Warnings

Beggs-Brill not applicable to $T_{pr} < 0.92$ The Beggs-Brill equation of state is normally not applicable to $T_{pr} < 0.92$.

Possible Errors

Beggs-Brill unknown amount of arguments The given number of arguments is unknown.

3.4.5 papay - Papay correlation

`z = papay(ppr, tpr)`

Computes the compressibility factor Z using the PaPay method using the pseudo-reduced pressure and temperature.

Arguments

ppr Pseudo-reduced pressure P_{pr} .

tpr Pseudo-reduced temperature T_{pr} .

Returns Compressibility factor Z .

Possible Errors

Papay unknown number of arguments The given number of arguments is unknown.

3.4.6 cnga - United States Natural Gas Association of California (CNGA) formula $z = \text{cnga}(p, t, g=1)$

Computes the compressibility factor Z using the United States Natural Gas Association of California (CNGA) formula.

Arguments

p Average pressure P_{avg} (Pa).

t Average temperature T_{avg} ($^{\circ}\text{K}$).

g Gas gravity ($g_{\text{air}} = 1$).

Returns Compressibility factor Z .

Possible Errors

CNGA unknown number of arguments The given number of arguments is unknown.

3.5 Pressure Drop

3.5.1 hazen_williams_p - Hazen-Williams pressure drop P

$$r = \text{hazen_williams_p}(q,d,c,sg=1)$$

Calculate the Hazen-Williams pressure drop across a pipeline. Common values for the roughness factor of the pipe *C* by material are provided in table 3.5.1.

Material	Range for C
Asbestos-Cement	140
Cast iron new	130
Cast iron after 10 years	[107, 113]
Cast iron after 20 years	[89, 100]
Cement-Mortar Lined Ductile Iron Pipe	140
Concrete	[100, 140]
Copper	[130, 140]
Steel	[90, 110]
Galvanized Iron	120
Polyethylene	150
Polyvinyl chloride	150
Fibre-reinforced plastic	150
Tin	130
Lead	[130, 140]

Arguments

- q** Volumetric flow rate *Q* (m³/h).
- d** Pipe internal diameter *D* (m).
- c** Roughness factor of the pipe *C*, see table above.
- sg** Liquid specific gravity *S_g*.

Returns Pressure drop due to friction *P* (kPa/km).

Possible Errors

Hazen-Williams factor must be >0 A negative or zero Hazen-Williams factor was supplied.

3.5.2 hazen_williams_q - Hazen-Williams flow rate Q

$q = \text{hazen_williams_q}(p, d, c, \text{sg}=1)$

Calculate the Hazen-Williams volumetric flow rate given the pressure drop due to friction. Common values for the roughness factor of the pipe C by material are provided in the in table 3.5.1.

Arguments

p Pressure drop due to friction P (kPa/km).

d Pipe internal diameter D (m).

c Roughness factor of the pipe C , see table 3.5.1.

sg Liquid specific gravity S_g .

Returns Volumetric flow rate (m^3/h).

Possible Errors

Hazen-Williams factor must be >0 A negative or zero Hazen-Williams factor was supplied.

3.5.3 hazen_williams_c - Hazen-Williams roughness factor C

$q = \text{hazen_williams_c}(p, q, d, \text{sg}=1)$

Calculate the Hazen-Williams roughness factor from the pressure loss due to friction and the volume flow.

Arguments

p Pressure drop due to friction P (kPa/km).

q Volumetric flow rate Q (m³/h).

d Pipe internal diameter D (m).

sg Liquid specific gravity S_g .

Returns Roughness factor of the pipe C , see table 3.5.1 for usual values.

Possible Warnings

Hazen-Williams calculated factor appears to be invalid The Hazen-Williams factor that was calculated is not plausible.

3.5.4 darcy_weisbach_p - Darcy-Weisbach pressure drop for P

`p = darcy_weisbach_p(q,d,fd)`

Calculates the pressure drop across a pipe using the Darcy-Weisbach equation.

Arguments

q Volumetric flow rate Q (m³/h).

d Pipe internal diameter D (m).

fd Darcy friction factor f_d .

Returns Pressure drop due to friction (kPa/km).

3.5.5 darcy_weisbach_q - **Darcy-Weisbach volume flow Q**

q = darcy_weisbach_q(p,d,fd)

Calculates the volume flow in a pipe using the Darcy-Weisbach equation.

Arguments

p Pressure drop due to friction (kPa/km).

d Pipe internal diameter D (m).

fd Darcy friction factor f_d .

Returns Volumetric flow rate Q (m³/h).

3.6 Oil Pipe Pressure Drop

3.6.1 aude_p - Aude pressure drop for P

$p = \text{aude_p}(q, d, v, sg, k)$

Calculates the pressure drop across a pipe using Aude's equation for petroleum products. The equation is valid for pipe sizes 8"-12" (200-300mm) in diameter for crude oil with Reynolds numbers [6000, 120000] and 6"-8" for Reynolds numbers ≥ 57000 for refined products.

Arguments

q Volumetric flow rate (m³/h).

d Pipe internal diameter (m).

v Liquid viscosity, centipoise.

k Pipe roughness/efficiency $k \in [0.90, 0.95]$.

sg Liquid specific gravity.

Returns Pressure drop due to friction (kPa/km).

Possible Warnings

Aude roughness factor out of the nominal range The provided roughness factor is not within $k \notin [0.90, 0.95]$

3.6.2 aude_q - Aude volume flow Q $q = \text{aude_q}(p, d, v, k, \text{sg}=1)$

Calculates the volume flow Q given a pressure drop due to friction P using Aude's equation.

Arguments

p Pressure drop due to friction (kPa/km).

d Pipe internal diameter (m).

v Liquid viscosity, centipoise.

k Pipe roughness/efficiency $k \in [0.90, 0.95]$.

sg Liquid specific gravity.

Returns Volumetric flow rate (m^3/h).

Possible Warnings

Aude roughness factor out of the nominal range The provided roughness factor is not within $k \notin [0.90, 0.95]$

3.6.3 shellmit_p - Shell-MIT pressure drop for P

`p = shellmit_p(q,d,v,sg)`

Calculates the pressure drop across a pipeline using the Shell-MIT equation suited for heavy crude oil and heated liquid.

Arguments

q Volumetric flow rate (m³/h).

v Liquid viscosity, centipoise.

d Pipe internal diameter (m).

sg Liquid specific gravity.

Returns Pressure drop due to friction (kPa/km).

3.6.4 shellmit_q - Shell-MIT volume flow Q

$q = \text{shellmit_q}(p, d, v, \text{sg})$

Calculates the pressure drop across a pipeline using the Shell-MIT equation suited for heavy crude oil and heated liquid.

Arguments

p Pressure drop due to friction (kPa/km).

v Liquid viscosity, centipoise.

d Pipe internal diameter (m).

sg Liquid specific gravity.

Returns Volumetric flow rate (m^3/h).

3.6.5 miller_p - Miller pressure drop for P

```
p = miller_p(q,d,pguess,v,sg=1,maxiter=10,threshold=1e-3)
```

Calculates the pressure drop across a pipeline using the Miller equation suitable for crude oil products.

Arguments

q Volumetric flow rate (m^3/h).

d Pipe internal diameter (m).

pguess Initial guess for the pressure result in kPa/km.

v Liquid viscosity, centipoise.

sg Liquid specific gravity.

maxiter Maximum number of iterations to try to converge.

threshold Iteration completion threshold.

Returns Pressure drop due to friction (kPa/km).

Possible Warnings

Miller equation not satisfied, but terminated due to iteration limit The function could not converge satisfactorily to the given threshold because it exceeded the maximum number of iterations dictated by the `maxiter` argument.

3.6.6 miller_q - Miller volume flow Q $q = \text{miller_q}(p, d, v, \text{sg}=1)$

Calculates the volume flow in a pipeline using the Miller equation suitable for crude oil products.

Arguments

p Pressure drop due to friction (kPa/km).

d Pipe internal diameter (m).

v Liquid viscosity, centipoise.

sg Liquid specific gravity.

Returns Volumetric flow rate (m^3/h).

3.7 Steam Pipe Pressure Drop

3.7.1 unwin_p - Unwin Formula ΔP

$p = \text{unwin_p}(w, l, d, v)$

Calculates the pressure drop of a steam pipe using the Unwin formula.

Arguments

w Steam flow rate (kg/h).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m^3/kg).

Returns Pressure drop ΔP (kPa).

3.7.2 unwin_w - Unwin Formula W $w = \text{unwin_w}(p, l, d, v)$

Calculates the pressure drop of a steam pipe using the Unwin formula for the volume flow given a pressure drop.

Arguments

p Pressure drop ΔP (kPa).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m^3/kg).

Returns Steam flow rate (kg/h).

3.7.3 babcock_p - Babcock Formula ΔP

$p = \text{babcock_p}(w, l, d, v)$

Calculates the pressure drop of a steam pipe using the Babcock formula.

Arguments

w Steam flow rate (kg/h).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m^3/kg).

Returns Pressure drop ΔP (kPa).

3.7.4 babcock_w - Babcock Formula W

$w = \text{babcock_w}(p, l, d, v)$

Calculates the pressure drop of a steam pipe using the Babcock formula for the volume flow given a pressure drop.

Arguments

p Pressure drop ΔP (kPa).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m^3/kg).

Returns Steam flow rate (kg/h).

3.7.5 fritzche_p - Fritzche Formula ΔP

`p = fritzche_p(w,l,d,v)`

Calculates the pressure drop of a steam pipe using the Fritzche formula.

Arguments

w Steam flow rate (kg/h).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m³/kg).

Returns Pressure drop ΔP (kPa).

3.7.6 fritzche_w - Fritzche Formula W

`w = fritzche_w(w,l,d,v)`

Calculates the pressure drop of a steam pipe using the Fritzche formula for the volume flow given a pressure drop.

Arguments

p Pressure drop ΔP (kPa).

l Pipe length (m).

d Pipe diameter (m).

v Specific volume (m^3/kg).

Returns Steam flow rate (kg/h).

3.8 Compressible Flow

3.8.1 panhandle_a_q - Panhandle A for flow Q

q = panhandle_a_q(l,d,p1,p2,pb,tb,tf,z,e,sg=1)

Calculate the volume flow Q using the Panhandle A equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

z Gas compressibility factor.

e Pipeline efficiency factor.

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.2 panhandle_b_q - Panhandle B for flow Q

q = panhandle_b_q(l,d,p1,p2,pb,tb,tf,z,e,sg=1)

Calculate the volume flow Q using the Panhandle B equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

z Gas compressibility factor.

e Pipeline efficiency factor.

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.3 weymouth_q - Weymouth for flow Q

`q = weymouth_q(l,d,p1,p2,pb,tb,tf,z,e,sg=1)`

Calculate the volume flow Q using the Weymouth equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b ($^{\circ}$ K).

tf Average temperature T_f ($^{\circ}$ K).

z Gas compressibility factor.

e Pipeline efficiency factor.

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.4 spitzglass_q - Spitzglass for flow Q

`q = spitzglass_q(type,l,d,p1,p2,pb,tb,tf,z,e,sg=1)`

Calculate the volume flow Q using the Spitzglass equation.

Arguments

type Pressure drop type, this can be either of:

- low Low pressure drop Spitzglass equation.
- high High pressure drop Spitzglass equation

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b ($^{\circ}\text{K}$).

tf Average temperature T_f ($^{\circ}\text{K}$).

z Gas compressibility factor.

e Pipeline efficiency factor.

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.5 oliphant_q - Oliphant for flow Q

`q = oliphant_q(type,l,d,p1,p2,pb,tb,tf,sg=1)`

Calculate the volume flow Q using the Oliphant equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.6 igt_q - IGT for flow Q

`q = igt_q(l,d,p1,p2,pb,tb,tf,z,e,mu,sg=1)`

Calculate the volume flow Q using the IGT equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

z Gas compressibility factor.

e Pipeline efficiency factor.

mu Average viscosity in the pipeline (Pa · s).

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.7 muller_q - Muller for flow Q

`q = muller_q(l,d,p1,p2,pb,tb,tf,z,e,mu,sg=1)`

Calculate the volume flow Q using the Muller equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

z Gas compressibility factor.

e Pipeline efficiency factor.

mu Average viscosity in the pipeline (Pa · s).

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.8.8 fritzsche_q - Fritzsche for flow Q

`q = fritzsche_q(l,d,p1,p2,pb,tb,tf,z,e,sg=1)`

Calculate the volume flow Q using the Fritzsche equation.

Arguments

l Length of the pipe L (m).

d Diameter of the pipe D (m).

p1 Upstream pressure P_1 (kPa).

p2 Downstream pressure P_2 (kPa).

pb Base pressure P_b (kPa).

tb Base temperature T_b (°K).

tf Average temperature T_f (°K).

z Gas compressibility factor.

e Pipeline efficiency factor.

sg Gas gravity ($g_{\text{air}} = 1$).

Returns Volume flow Q in m^3/h .

3.9 Miscellaneous

3.9.1 average_pressure - Average pressure P_{avg}

`p = average_pressure(p1, p2)`

Calculate the average pressure between two measurement points P_1 and P_2 using:

$$P_{\text{avg}} = \frac{2}{3} \left(P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2} \right)$$

Arguments

p1 Pressure at location one P_1 .

p2 Pressure at location two P_2 .

Returns Average pressure P_{avg} in the same unit as the arguments.

3.9.2 reynolds_number - **Reynolds Number** Re

```
re = reynolds_number(v,d,nu)
re = reynolds_number(v,d,mu,rho)
```

Calculate the dimensionless Reynolds number given the velocity and diameter of a pipe as well as either the kinematic viscosity or the density as well as dynamic viscosity.

$$\text{Re} = \frac{DV}{\nu} = \frac{VD\rho}{\mu}$$

Arguments

v Velocity (m/s).

d Diameter (m).

nu Kinematic viscosity (m²/s).

mu Dynamic viscosity (Pa · s).

rho Density (kg/m³).

Returns Reynolds number, Re.

Possible Errors

Reynolds number unknown amount of arguments The function must either be supplied with 3 arguments, *V*, *D* and *ν* or with 4 arguments, *V*, *D*, *μ* and *ρ*.