Pipeline Toolbox Function Reference Manual
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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 = 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 = 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** m^3/h

```
y = bblh_m3h(x)
```

Converts oil barrels per hour (bbl/h) to cubic metres per hour (m^3/h).

Arguments

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

Returns Value in cubic metres per hour (m^3/h).

3.1.4 `m3h_bblh` - m^3/h **to** bbl/h

```
y = m3h_bblh(x)
```

Converts cubic metres per hour (m^3/h) to oil barrels per hour (bbl/h).

Arguments

x Value in cubic metres per hour (m^3/h).

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

3.1.5 `galh_m3h` - gal/h to m^3/h

```
y = galh_m3h(x)
```

Converts gallons per hour (gal/h) to cubic metres per hour (m^3/h).

Arguments

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

Returns Value in cubic metres per hour (m^3/h).

3.1.6 `m3h_galh` - m^3/h **to** gal/h

```
y = m3h_galh(x)
```

Converts cubic metres per hour (m^3/h) to gallons per hour (gal/h).

Arguments

x Value in cubic metres per hour (m^3/h).

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

3.1.7 `psi_kpa` - psi **to** kPa

```
y = 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 = 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 = 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 = 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 = 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 = 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` - ft^3/lb **to** m^3/kg

```
y = ft3lb_m3kg(x)
```

Converts cubic feet per pound (ft^3/lb) to cubic metres per kilogram (m^3/kg).

Arguments

x Value in cubic feet per pound (ft^3/lb).

Returns Value in cubic metres per kilogram (m^3/kg).

3.1.14 `m3kg_ft3lb` - m^3/kg to ft^3/lb

```
y = m3kg_ft3lb(x)
```

Converts cubic metres per kilogram (m^3/kg) to cubic feet per pound (ft^3/lb).

Arguments

x Value in cubic metres per kilogram (m^3/kg).

Returns Value in cubic feet per pound (ft^3/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.

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

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 `haaland` - Haaland friction factor

```
f = 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.

3.2.3 `swamee_jain` - Swamee-Jain friction factor

```
f = 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 $1e-6 \leq \varepsilon/D \leq 0.05$.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε.

re Reynolds number

Returns Darcy friction factor f, dimensionless.

Possible Errors

Swamee-Jain is only valid for 5000 <= Re <= 1e8 The given Reynolds number is out of range.

Swamee-Jain is only valid for 1e-6 <= e/D <= 0.05 The given pipe roughness/diameter fraction is out of range.

3.2.4 `serghides` - Serghides friction factor

```
f = 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.

3.2.5 `goudar_sonnad1` - Goudar-Sonnad (2006) friction factor

```
f = 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.

3.2.6 `goudar_sonnad2` - Goudar-Sonnad (2011) friction factor

```
f = 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.

3.2.7 `brkic` - Brkic friction factor

```
f = 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.

3.2.8 `brkic_praks` - Brkic-Praks friction factor

`f = 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.

3.2.9 `praks_brkic` - Praks-Brkic friction factor

```
f = 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.

3.2.10 `niazkar` - Niazkar friction factor

```
f = 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.

3.2.11 `moody` - Moody friction factor

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

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

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 <= Re <= 5e8 The given Reynolds number is out of range.

Moody approximation only valid within 0 <= e/D <= 0.01 The given pipe roughness/diameter fraction is out of range.

3.2.12 `wood` - Wood friction factor

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

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

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 <= Re <= 5e7 The given Reynolds number is out of range.

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

3.2.13 `eck` - Eck friction factor

```
f = 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.

3.2.14 `churchill1` - Churchill (1973) friction factor

```
f = 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.

3.2.15 `churchill2` - Churchill (1977) friction factor

```
f = churchill2(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.

3.2.16 `jain` - Jain friction factor

```
f = 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.

3.2.17 `chen` - Chen friction factor

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

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

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 <= Re <= 4e8 The given Reynolds number is out of range.

3.2.18 `round_friction` - Round friction factor

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

Calculate the Chen approximation of the Colebrook-White equation.

The name of the function has been set to `round_friction` as to not name collide with rounding functions.

Arguments

d Pipe internal diameter (m).

e Pipe effective roughness ε.

re Reynolds number

Returns Darcy friction factor f, dimensionless.

3.2.19 `barr` - Barr friction factor

```
f = 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.

3.2.20 `zigrang_sylvester1` - Zigrang-Sylvester friction factor

```
f = 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.

3.2.21 `zigrang_sylvester2` - Zigrang-Sylvester friction factor

```
f = 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.

3.2.22 `tsal` - Tsal friction factor

```
f = 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.

3.2.23 `manadilli` - Manadilli friction factor

```
f = manadilli(d,e,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 <= Re <= 1e8 The given Reynolds number is out of range.

Manadilli approximation is only valid for 0 <= e/D <= 0.05 The given pipe roughness/diameter fraction is out of range.

3.2.24 `romeo_royo_monzon` - Romeo-Royo-Monzon friction factor

```
f = 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.

3.2.25 `vatankhah_kouchakzadeh` - Vatankhah-Kouchakzadeh friction factor

```
f = 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.

3.2.26 `buzzelli` - Buzzelli friction factor

```
f = 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.

3.2.27 `cheng` - Cheng friction factor

```
f = 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.

3.2.28 `avci_kargoz` - Avci-Kargoz friction factor

```
f = 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.

3.2.29 `evangelides` - Evangelides-Papaevangelou-Tzimopoulos friction factor

```
f = 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.

3.2.30 `fang` - Fang friction factor

`f = 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.

3.2.31 `alashkar` - Alashkar friction factor

```
f = 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.

3.2.32 `bellos` - Bellos-Nalbantis-Tsakiris friction factor

```
f = 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.

3.2.33 `tkachenko1` - Tkachenko-Mileikovskyi friction factor

```
f = tkachenko1(d,e,re)
```

Calculate the Tkachenko-Mileikovskyi approximation of the Colebrook-White equation valid for $2320 \leq \mathrm{Re} \leq 10^9$ and $0 \leq \varepsilon/D \leq 0.65$.

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 <= Re <= 1e9 The given Reynolds number is out of range.

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

3.2.34 `tkachenko2` - Tkachenko-Mileikovskyi friction factor

```
f = tkachenko2(d,e,re)
```

Calculate the Tkachenko-Mileikovskyi approximation of the Colebrook-White equation valid for $2320 \leq \mathrm{Re} \leq 10^9$ and $0 \leq \varepsilon/D \leq 0.65$.

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 <= Re <= 1e9 The given Reynolds number is out of range.

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

3.2.35 `blasius` - Blasius friction factor

```
f = 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 < Re < 1e5 The given Reynolds number is out of range.

3.2.36 `koo` - Koo friction factor

`f = koo(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 < Re < 1e7 The given Reynolds number is out of range.

3.2.37 `nikuradse_reichert` - Nikuradse-Reichert friction factor

`f = nikuradse_reichert(re)`

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

Arguments

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.

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:

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

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:

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

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.

3.3.2 `germano_number` - Germano number Gn

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

Computes the *Germano number* Gn 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:

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

Arguments

re Reynolds number Re.

r Helix radius R_H (m).

p Helix pitch p (m).

cr Curvature ratio (dimensionless)

Returns Germano number Gn, dimensionless.

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 $11.6 \leq \mathrm{De} \leq 2000$.

Arguments

re Reynolds number Re.

de Dean number De.

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

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.

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.

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.

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.

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.

3.4 Compressebility

3.4.1 `hall_yarborough` - Hall-Yarborough equation of state

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

Computes the compressebility 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 Compressebility factor Z.

Possible Errors

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

3.4.2 `dranchuck_purvis_robinson` - Dranchuk-Purvis-Robinson equation of state

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

Computes the compressebility 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 Compressebility factor Z.

3.4.3 `dranchuck_abou_kassem` - Dranchuk & Abou-Kassem equation of state

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

Computes the compressebility 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 Compressebility factor Z.

Possible Errors

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

3.4.4 `beggs_brill` - Beggs-Brill equation of state

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

Computes the compressebility 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 Compressebility factor Z.

Possible Warnings

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

3.4.5 `papay` - Papay correlation

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

Computes the compressebility 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 Compressebility factor Z.

3.4.6 `cnga` - United States Natural Gas Association of California (CNGA) formula

```
z = cnga(p,t,g=1)
```

Computes the compressebility 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} (°K).

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

Returns Compressebility factor Z.

3.5 Pressure Drop

3.5.1 `hazen_williams_p` - Hazen-Williams pressure drop P

```
r = 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 (m^3/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 = hazen_williams_q(p,d,c,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 = hazen_williams_c(p,q,d,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 (m^3/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 (m^3/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 (m^3/h).

3.6 Oil Pipe Pressure Drop

3.6.1 `aude_p` - Aude pressure drop for P

```
p = 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 (m^3/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 $k \not\in [0.90, 0.95]$

3.6.2 `aude_q` - Aude volume flow Q

```
q = aude_q(p,d,v,k,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 $k \not\in [0.90, 0.95]$

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 (m^3/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 = shellmit_q(p,d,v,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 = miller_q(p,d,v,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 = 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 = 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 = 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 = 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 (m^3/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 compressebility 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 compressebility 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 (°K).

tf Average temperature T_f (°K).

z Gas compressebility 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 (°K).

tf Average temperature T_f (°K).

z Gas compressebility 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 compressebility factor.

e Pipeline efficiency factor.

mu Average viscosity in the pipeline ($\mathrm{Pa \cdot s}$).

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

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 compressebility factor.

e Pipeline efficiency factor.

mu Average viscosity in the pipeline ($\mathrm{Pa \cdot s}$).

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

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 compressebility 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:

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

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 viscocity.

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

Arguments

v Velocity (m/s).

d Diameter (m).

nu Kinematic viscocity (m^2/s).

mu Dyanamic viscocity ($\mathrm{Pa} \cdot \mathrm{s}$).

rho Density (kg/m^3).

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.