Physical properties of Natural gas

Oil and gas engineers need to accurate values of the transport and thermodynamics properties of natural gas over a broad range of temperatures and pressures, and compositions. This data is needed to size pipes, pumps, valves, heat exchangers, compressors and other items of process plant.

Inaccurate data compounded over the many items of process equipment can amplify risk, both to cost and safety.

Maple Flow lets you calculate the transport properties of several standard natural gas mixtures (Gulf Coast, Amarillo, Ekofisk, High N2, High N2/O2), and your own custom mixtures. The functionality is available in the ThermophysicalData package.

Name	Gult Coast (GulfCoast.mix)	Amarillo (Amarillo.mix)	Ekofisk (Ekofisk.mix)	High N2 (HighN2.mix)	High N2/CO2 (HighCO2.mix)
Methane	96.5222	90.6724	85.9063	81.441	81.212
Ethane	1.8186	4.5279	8.4919	3.3	4.303
Propane	0.4696	0.828	2.3015	0.605	0.895
Nitrogen	0.2595	0.31284	1.0068	13.465	5.702
Carbon Dioxide	0.5956	0.4676	1.4954	0.985	7.585
i-Butane	0.0977	0.1037	0.3486	0.1	0.151
n-Butane	0.1007	0.1563	0.3506	0.104	0.152
i-Pentane	0.0473	0.0321	0.0509	0	0
n-Pentane	0.0324	0.0443	0.048	0	0
n-Hexane	0.0664	0.0393	0	0	0

Table 1 : Composition (Mole fraction) in %

This application shows how to calculate properties with a Helmholtz energy approach, and includes density, viscosity, specific heat capacity, compressibility factor, Thomson coefficient and more. And, these properties are instantly used in your design calculation.

Parameters

The type of gas mixture, pressure and temperature are given as follow.

Gas name GasName := "GulfCoast.mix"

Pressure $P_{gas} := 14.73\ \mathrm{psi}$

Temperature $T_F := 60\ \mathrm{degF}$

Basic property calls for Predefined natural gas mixtures

The following properties can be obtained with the package based on above.

Temperature in Kelvin

$T_K :=$ temperature_conversion$\left(T_F, \text{"degF"}, \text{"K"}\right) = 288.706\ \mathbf{K}$

Note:
Function calls in ThermophysicalData package is better to be with temperature in Kelvin.
The unit of temperature can be converted with temperature_conversion() function defined in the Code region.

Density

ThermophysicalData:-Property$\left(\text{density, GasName, pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.712\ \frac{\mathbf{kg}}{\mathbf{m}^3}$

Viscosity

ThermophysicalData:-Property$\left(\text{viscosity, GasName, pressure} = P_{gas}, \text{temperature} = T_K\right) = 7.30 \times 10^{-6}\ \frac{\mathbf{lb}}{\mathbf{ft \cdot s}}$

Compressibility factor

ThermophysicalData:-Property$\left(\text{Z, GasName, pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.998$

Molar mass

ThermophysicalData:-Property$(\text{molarmass, GasName, useunits}) = 0.017\ \frac{\mathbf{kg}}{\mathbf{mol}}$

Different mixtures have different properties. Here, we compare the specific heat capacity for the five predefined mixtures.

List of gases

ListGas := ["Amarillo.mix", "Ekofisk.mix", "GulfCoast.mix", "HighN2.mix", "HighCO2.mix"]

Amarillo

$\text{ThermophysicalData:-Property}\left(C, \text{ListGas}[1], \text{pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.497 \frac{\text{Btu}}{\text{lb °F}}$

Ekofisk

$\text{ThermophysicalData:-Property}\left(C, \text{ListGas}[2], \text{pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.486 \frac{\text{Btu}}{\text{lb °F}}$

Gulf Coast

$\text{ThermophysicalData:-Property}\left(C, \text{ListGas}[3], \text{pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.515 \frac{\text{Btu}}{\text{lb °F}}$

High N2

$\text{ThermophysicalData:-Property}\left(C, \text{ListGas}[4], \text{pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.455 \frac{\text{Btu}}{\text{lb °F}}$

High N2/CO2

$\text{ThermophysicalData:-Property}\left(C, \text{ListGas}[5], \text{pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.439 \frac{\text{Btu}}{\text{lb °F}}$

Custom Mixtures

In this section, the calculation of the custom gas mixtures is explained. The same data can be obtained by manually specifying the mixture composition. For example, this is the density of the Gulf Coast mixture.

List of composition

ListComp1 := ["methane", "ethane", "propane", "nitrogen", "CO2", "ISOBUTAN", "butane", "IPENTANE", "PENTANE", "Hexane"]

Composition

MF1 := [0.965222, 0.018186, 0.004596, 0.002595, 0.005956, 0.000977, 0.001007, 0.000473, 0.000324, 0.000664]

String for gas mixture

case1_mixture := gas_mixture(ListComp1, MF1, "HEOS")

Note:
- In this case, HEOS : Helmholtz Equation Of State is used.
- gas_mixture() is defined in code region, which is to generate a string from List of composition, Mole fraction and a type of gasmixture.
- Also can specify the setting of composition with the handwrittern string
  e.g. "HEOS::methane[.965222]&ethane[.18186e-1]&propane[.4596e-2]&nitrogen[.2595e-2]&CO2[.5956e-2]&ISOBUTAN[.977e-3]&butane[.1007e-2]&IPENTANE[.473e-3]&PENTANE[.324e-3]&Hexane[.664e-3]"

Density

ThermophysicalData:-Property$\left(\text{density, case1_mixture, pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.712\ \frac{kg}{m^3}$

Manually specifying the mixture composition let you use the Soave-Redilich-Kwong (SRK) and Peng-Robinson (PR) cubic equations of state to calculate some (but not all) of the properties

Composition

ListComp2 := ["methane", "ethane", "propane", "nitrogen", "CO2", "ISOBUTAN", "butane", "IPENTANE", "PENTANE", "Hexane"]

MF2 := [0.965222, 0.018186, 0.004596, 0.002595, 0.005956, 0.000977, 0.001007, 0.000473, 0.000324, 0.000664]

case2_mixture := gas_mixture(ListComp2, MF2, "SRK")

Density

ThermophysicalData:-Property$\left(\text{density, case2_mixture, pressure} = P_{gas}, \text{temperature} = T_K\right) = 0.044\ \frac{lb}{ft^3}$

Composition

ListComp3 := ["methane", "ethane", "propane", "nitrogen", "CO2", "ISOBUTAN", "butane", "IPENTANE", "PENTANE", "Hexane"]

MF3 := [0.965222, 0.018186, 0.004596, 0.002595, 0.005956, 0.000977, 0.001007, 0.000473, 0.000324, 0.000664]

case3_mixture := gas_mixture(ListComp3, MF3, "PR")

Density

ThermophysicalData:-Property(density, case3_mixture, pressure = P_{gas}, temperature = T_K) = $0.044 \frac{lb}{ft^3}$

Density of Gulf Coast Natural Gas as a Function of Temperature

Here we plot the density of the Gulf Coast mixture over a range of temperatures and at a pressure of 10 bar.

densityTP := (T_x, p_x) ThermophysicalData:-Property(density, GasName, temperature = T_x, pressure = p_x)

plot(densityTP(T, 10^5), T = 300 ..500, numpoints = 15, thickness = 2, style = line,
title = "Density of Gulf Coast Natural Gas\n Caclulated from Helmholtz Energy functions",
titlefont = [Arial, 14], labels = ["Density (kg/m^3)", "Temperature (K)"], labeldirections = [horizontal, vertical],
labelfont = [Arial], gridlines, axesfont = [Arial], size = [800, 500]) =