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Application Demonstration

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Physical Properties of Natural Gas

Introduction

Oil and gas engineers need accurate values of the transport and thermodynamic 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 lets you calculate the transport properties of several standard natural gas mixtures (Gulf Coast, Amarillo, Ekofisk, High N_2 and High N_2/O_2), and your own custom mixtures. The functionality is available in the ThermophysicalData package, powered by the open source CoolProp project.

	Gulf Coast	Amarillo	Ekofisk	High N_2	High N_2/CO_2
Name	GulfCoast.mix	Amarillo.mix	Ekofisk.mix	HighN2.mix	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	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 in Mole %

Properties are calculated with a Helmholtz energy approach, and includes density, viscosity, specific heat capacity, compressibility factor, Joule-Thomson coefficient and more. This data is instantly accessible in Maple's interactive computing environment - this means you can use all of Maple's plotting, solving and optimization routines with the data, and employ units as a dimensionality check.

Basic Property Calls for Predefined Natural Gas Mixtures

```
> with(ThermophysicalData) :
```

Here is the density, viscosity, compressibility factor, molar mass and specific gravity of the Gulf Coast mixture (if you use units with the state values, then the result has a unit).

```
> Property(density, "GulfCoast.mix", temperature = 60 degF, pressure = 14.73 psi)
```

$$44.47 \times 10^{-3} \frac{\mathrm{lb}}{\mathrm{ft}^3} \quad (2.1)$$

```
> Property(viscosity, "GulfCoast.mix", temperature = 60 degF, pressure = 14.73 psi)
```

$$7.30 \times 10^{-6} \frac{\mathrm{lb}}{\mathrm{ft\,s}} \quad (2.2)$$

```
> Property(Z, "GulfCoast.mix", temperature = 60 degF, pressure = 125 psi)
```

$$0.9818813717 \quad (2.3)$$

```
> Property(molar_mass, "GulfCoast.mix", useunits)
```

$$16.80 \times 10^{-3} \frac{\mathrm{kg}}{\mathrm{mol}} \quad (2.4)$$

$$> \frac{Property(molar\_mass, \text{"GulfCoast.mix"})}{Property(molar\_mass, \text{"air"})}$$

$$0.5799741257 \quad (2.5)$$

Different mixtures have, of course, different properties. Here, we compare the specific heat capacity for the five predefined mixtures at 60°F and 14.73 psi.

```
> Property(C, "Amarillo.mix", temperature = 60 degF, pressure = 14.73 psi);
  Property(C, "Ekofisk.mix", temperature = 60 degF, pressure = 14.73 psi);
  Property(C, "GulfCoast.mix", temperature = 60 degF, pressure = 14.73 psi);
  Property(C, "HighN2.mix", temperature = 60 degF, pressure = 14.73 psi);
  Property(C, "HighCO2.mix", temperature = 60 degF, pressure = 14.73 psi)
```

$$0.497 \frac{\mathrm{Btu}}{\mathrm{lb\,°F}}$$

$$0.486 \frac{\mathrm{Btu}}{\mathrm{lb\,°F}}$$

$$0.515 \frac{\mathrm{Btu}}{\mathrm{lb\,°F}}$$

$$0.455 \frac{\mathrm{Btu}}{\mathrm{lb\,°F}}$$

(2.6)

$$0.439\ \frac{\text{Btu}}{\text{lb °F}} \tag{2.6}$$

Custom Mixtures

The same data can be extracted by manually specifying the mixture composition.For example, this is the density of the Gulf Coast mixture

```
> Property(density,
    "HEOS::methane[0.965222]&ethane[0.018186]&propane[0.004596]&nitrogen[0.002595]
    &CO2[0.005956]&ISOBUTAN[0.000977]&butane[0.001007]&IPENTANE[0.000473]
    &PENTANE[0.000324]&Hexane[0.000664]", temperature = 60 degF, pressure = 14.73 psi)
```

$$44.47 \times 10^{-3}\ \frac{\text{lb}}{\text{ft}^3} \tag{3.1}$$

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

```
> Property(density,
    "SRK::methane[0.965222]&ethane[0.018186]&propane[0.004596]&nitrogen[0.002595]
    &CO2[0.005956]&ISOBUTAN[0.000977]&butane[0.001007]&IPENTANE[0.000473]
    &PENTANE[0.000324]&Hexane[0.000664]", temperature = 60 degF, pressure = 14.73 psi)
```

$$44.47 \times 10^{-3}\ \frac{\text{lb}}{\text{ft}^3} \tag{3.2}$$

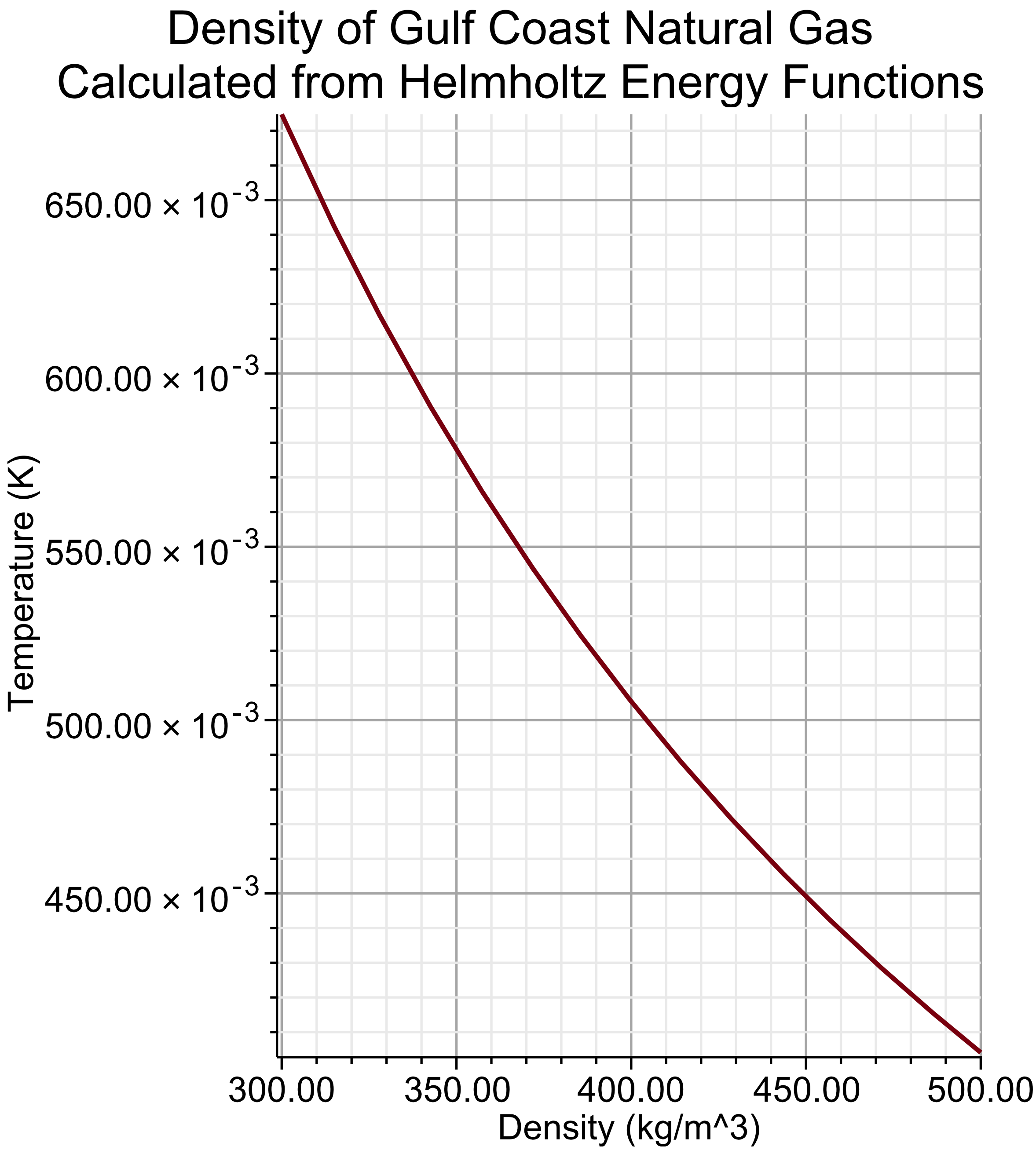
```
> Property(density,
    "PR::methane[0.965222]&ethane[0.018186]&propane[0.004596]&nitrogen[0.002595]
    &CO2[0.005956]&ISOBUTAN[0.000977]&butane[0.001007]&IPENTANE[0.000473]
    &PENTANE[0.000324]&Hexane[0.000664]", temperature = 60 degF, pressure = 14.73 psi)
```

$$44.49 \times 10^{-3}\ \frac{\text{lb}}{\text{ft}^3} \tag{3.3}$$

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 := (temp, press) → Property('density', "GulfCoast.mix",'temperature'= temp,
    'pressure'= press) :
> plot(densityTP(T, 10^5), T = 300 ..500, numpoints = 15, thickness = 2, adaptive = false, style = line,
    title = "Density of Gulf Coast Natural Gas\nCalculated from Helmholtz Energy Functions",
    titlefont = [Arial, 16], labels = ["Density (kg/m^3)", "Temperature (K)"], labeldirections
    = [horizontal, vertical], labelfont = [Arial], size = [800, 500], gridlines, axesfont = [Arial])
```


Density of Gulf Coast Natural Gas
Calculated from Helmholtz Energy Functions
Temperature (K)
650.00 × 10^-3
600.00 × 10^-3
550.00 × 10^-3
500.00 × 10^-3
450.00 × 10^-3
300.00
350.00
400.00
450.00
500.00
Density (kg/m^3)

>