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1 Features

Composition of components in mole %, volume %, weight % normative and ultimate weight % for C-H-N-O-S-He-Ar

Molar mass & gas constant according to DIN1871-1999, ISO6976-1995, ASTM D3588-1998, extendable

Low & high heat value according to DIN51850-1980, ISO6976-1995 (0°C 15°C 25°C), ASTM D3588-1998 extendable

Caloric properties according to AGA8-DC92 (ISO12213-2) and ISO20765-1-2005 (Helmholtz free energy approach):

- Density
- Compression factor
- Inner energy
- Enthalpy
- Entropy
- Heat capacity cp
- Heat capacity cv
- Isentropic exponent
- Joule Thomson coefficient
- Speed of sound

Transport Properties according to Schley VDI Reihe 7 No. 418-2001

- Dynamic viscosity
- Heat circuit capacity

Optional flow Calculation all devices in ISO5167-2003

- Optional calibrated discharge coefficient
- Optional diameter correction for temperature

2 About the Tool

I developed this tool to have a small, simple and fast calculation for real gas properties. The tool is compiled from FORTRAN code and runs on any DOS or WINDOWS based computer. Input and Output files are ASCII Text. A text editor with <overwrite> option is suggested i.e. KEDIT <http://kedit.com> or TEXTPAD <http://textpad.com>.

Development of UNIX version or graphic interface is possible upon request.

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3 Installation

There is no installation tool required and there is no copy protection or expiration on the files.

The following files need to be copied into a single directory (data files for heat values & molar mass, input file actual gas conditions, program file, sample batch-file), total size 544 kB.

- astm.dta
- din.dta
- iso00.dta
- iso15.dta
- iso25.dta
- pginput.txt
- pginput.sav
- progas.exe
- progas.bat

4 Run the program

Start progas.bat

The self-explaining input file pginput.txt is opened. Choose the overwrite option of your editor before updating any requested value. Lines must not be deleted nor shall be changed positions of any comment information. Otherwise the program will not run correct or will not run at all. In case of damaging the input file - copy the input backup file pginput.sav to pginput.txt and try again. Save the input file before leaving the editor.

The program will start automatically. Comments like overrange for given conditions are shown on the screen. In the example below the H2 content in the gas is outside recommended range and the orifice pressure drop is smaller than specified according to ISO 5167.

[VIEW FROM DOS SHELL](#)

```
D:\Progs\TD\Progas>"c:\program files\textpad\textpad" PGINPUT.TXT

D:\Progs\TD\Progas>PROGAS.EXE
H2 + H2O + H2S out of rec. Range for Transport Properties
Sum = 9.520 Mol% > 0.1 Mol%
H2 + H2O + H2S out of rec. Range for Transport Properties
Sum = 9.520 Mol% > 0.1 Mol%
H2 + H2O + H2S out of rec. Range for Transport Properties
Sum = 9.520 Mol% > 0.1 Mol%
H2 + H2O + H2S out of rec. Range for Transport Properties
Sum = 9.520 Mol% > 0.1 Mol%
H2 + H2O + H2S out of rec. Range for Transport Properties
Sum = 9.520 Mol% > 0.1 Mol%
p2/p1>0.98 in MDOTOR p2/p1 = 0.9957E+00

D:\Progs\TD\Progas>Pause
Press any key to continue . . .
```

A pause will give sufficient time to read the comments and confirm for proceeding to the final step.

The results are written into the output file pgsresult.txt, which is displayed at the end of the batch-procedure.

Using the editor the output file could be renamed thereafter, e.g. result_gas1.doc for future reference and easy printing with fixed width font.

5 Input File pginput.txt

Below is a sample input file. It uses the gas composition from example 4 (page 39 of ISO 20765), so also the results can be compared with the ISO code.

PGINPUT.TXT

```
GAS 4 ISO 20765-1 2005(E)
100.0      ,'= gas pressure.....[bar absolut]'
76.85     ,'= gas temperature.....[deg C]'
0.432     ,'= pressure drop across flow element 0 no flow calculation.....[bar]'
0.2025    ,'= pipe diameter.....[m]'
22.3      ,'= pipe diameter reference temperature.....[deg C]'
11        ,'= pipe material 10NOcorr 11steel1 12steel2 13steel3 14steel4 15steel5....[-]'
0.1229    ,'= flow element diameter orifice/nozzle/venturi nozzle/venturi tube.....[m]'
8.33      ,'= flow element diameter reference temperature.....[deg C]'
15        ,'= flow element material 16steel6 17SnBz4 18E-Cu 19Rg9 20Ms63 21Ni 22HaC..[-]'
0.        ,'= discharge coefficient 1 from calibration.0NO calibration.....[-]'
0.6255    ,'= discharge coefficient 2 from calibration.....[-]'
0.62345D5 ,'= reynoldsnumber 1 from calibration with pipe diameter.....[-]'
0.62345D7 ,'= reynoldsnumber 2 from calibration with pipe diameter.....[-]'
ISO00.DTA ,'= data filename for heat values & molar masses.....[-]'
0         ,'= gas composition given in.....0[mol%] 1[vol%] 2[wght%]'
3         ,'= flow element 1ORcor 2ORfla 3ORdd2 4NOisa 5NOLra 6VEnoz 7VTasc 8VTmac 9VTrw'
9.5       ,'= (1)    ,%,H2.....hydrogen
0.02      ,'= (2)    ,%,He.....helium
0.01      ,'= (3)    ,%,H2O.....water vapor
1.0       ,'= (4)    ,%,CO.....carbon monoxide
10.       ,'= (5)    ,%,N2.....nitrogen
0.01      ,'= (6)    ,%,O2.....oxygen
0.01      ,'= (7)    ,%,H2S.....hydrogen sulfide
0.01      ,'= (8)    ,%,Ar.....argon
1.6       ,'= (9)    ,%,CO2.....carbon dioxide
73.50     ,'= (10)   ,%,CH4.....methane
3.3       ,'= (11)   ,%,C2H6.....ethane
0.74      ,'= (12)   ,%,C3H8.....propane
0.08      ,'= (13)   ,%,i-C4H10....iso-butane
0.08      ,'= (14)   ,%,n-C4H10....n-butane
0.        ,'= (15)   ,%,neo-C5H12...neo-pentane
0.04      ,'= (16)   ,%,i-C5H12....iso-pentane
0.04      ,'= (17)   ,%,n-C5H12....n-pentane
0.02      ,'= (18)   ,%,n-C6H14....n-hexane
0.01      ,'= (19)   ,%,n-C7H16....n-heptane
0.01      ,'= (20)   ,%,n-C8H18....n-octane
0.01      ,'= (21)   ,%,n-C9H20....n-nonane
0.01      ,'= (22)   ,%,n-C10H22...n-decane
0.        ,'= (23)   ,%,SO2.....sulfur dioxide
0.        ,'= (24)   ,%,c-C5H10....cyclopentane
0.        ,'= (25)   ,%,c-C6H12....cyclohexane
0.        ,'= (26)   ,%,CH3-C5H9....methylcyclopentane
0.        ,'= (27)   ,%,CH3-C6H11...methylcyclohexane
0.        ,'= (28)   ,%,2,2-i-C6H14..2,2-dimethylbutane
0.        ,'= (29)   ,%,2,3-i-C6H14..2,3-dimethylbutane
0.        ,'= (30)   ,%,C6H6.....benzene
0.        ,'= (31)   ,%,C7H8.....toluene
0.        ,'= (32)   ,%,o-C8H10....o-xylene
```

5.1 Disable flow calculation

To disable the flow calculation the pressure drop should be set to zero.

PGINPUT.TXT

```
0.0      ,'= pressure drop across flow element 0 no flow calculation.....[bar]'
```

5.2 The data files

The data files are editable and contain relevant heat values and molar masses according to different codes. In the example ISO00.dta is given and it comes from ISO6976-1995 for Molar Mass & Calorific Values @0degC.

PGINPUT.TXT

ISO00.DTA ,'= data filename for heat values & molar masses.....[-]'

ISO00.DTA

ISO6976-1995 for Molar Mass & Calorific Values @0degC
 ---+---1---+---2*---+---3*---+---4*---+---5*---+---6*---+---7*---+---8*---+---9*---+---0
 all Z0&WB from ISO6976-95

Name	\$Code	Molar	CV sup	CV inf	z0 0C & WB =
	Chem. Formula	Mass	Comb 0C	Comb 0C	1.01325 SQRT(1-Z)
	CCHHOONNSSHEAR	g/ mol	kJ/ mol	kJ/ mol	bar
Hydrogen.....	H2	2.0159	286.63	241.56	1.0006 -0.0040
Helium.....	He	4.0026	0.	0.	1.0005 0.0006
Water Vapor.....	H2O	18.0153	45.074	0.	0.930 0.2646
Carbon Monoxide.....	CO	28.010	282.80	282.80	0.9993 0.0265
Nitrogen.....	N2	28.0135	0.	0.	0.9995 0.0224
Oxygen.....	O2	31.9988	0.	0.	0.9990 0.0316
Hydrogen Sulfide.....	H2S	34.082	562.94	517.87	0.990 0.1000
Argon.....	Ar	39.948	0.	0.	0.9990 0.0316
Carbon Dioxide.....	CO2	44.010	0.	0.	0.9933 0.0819
Methane.....	CH4	16.043	892.97	802.82	0.9976 0.0490
Ethane.....	C2H6	30.070	1564.34	1429.12	0.9900 0.1000
Propane.....	C3H8	44.097	2224.01	2043.71	0.9789 0.1453
iso-Butane.....	i-C4H10	58.123	2874.20	2648.83	0.958 0.2049
n-Butane.....	n-C4H10	58.123	2883.82	2658.45	0.9572 0.2069
neo-Pentane.....	neo-C5H12	72.150	3521.72	3251.28	0.943 0.2387
iso-Pentane.....	i-C5H12	72.150	3535.98	3265.54	0.937 0.2510
n-Pentane.....	n-C5H12	72.150	3542.89	3272.45	0.918 0.2864
n-Hexane.....	n-C6H14	86.177	4203.23	3887.71	0.892 0.3286
n-Heptane.....	n-C7H16	100.204	4862.87	4502.28	0.830 0.4123
n-Octane.....	n-C8H18	114.231	5522.40	5116.73	0.742 0.5079
n-Nonane.....	n-C9H20	128.258	6182.91	5732.17	0.613 0.6221
n-Decane.....	n-C10H22	142.285	6842.69	6346.88	0.434 0.7523
Sulfur Dioxide.....	SO2	64.065	0.	0.	0.976 0.1549
Cyclopentane.....	c-C5H10	70.134	3326.14	3100.77	0.935 0.2550
Cyclohexane.....	c-C6H12	84.161	3960.67	3690.23	0.897 0.3209
Methylcyclopentane.....	CH3-C5H9	84.161	3977.04	3706.60	0.902 0.3130
Methylcyclohexane.....	CH3-C6H11	98.188	4609.34	4293.82	0.855 0.3808
2,2-Dimethylbutane..	2,2-i-C6H14	86.177	4185.84	3870.32	0.916 0.2898
2,3-Dimethylbutane..	2,3-i-C6H14	86.177	4193.63	3878.11	0.910 0.3000
Benzene.....	C6H6	78.114	3305.03	3169.81	0.909 0.3017
Toluene.....	C7H8	92.141	3952.72	3772.42	0.849 0.3886
o-xylene.....	o-C8H10	106.167	4602.17	4376.80	0.737 0.5128
AIR	ML Z0 Z15 DL0	28.9626	0.99941	0.99958	1.292923

5.3 Flow Elements

Control parameter for the flow element

PGINPUT.TXT

3 ,'= flow element 1ORcor 2ORfla 3ORdd2 4NOisa 5NOlra 6VEnoz 7VTasc 8VTmac 9VTrw'

1	Orifice with Corner Tapping
2	Orifice with Flange Tapping
3	Orifice with d&d/2 Tapping
4	ISA 1932 Nozzle
5	Long Radius Nozzle
6	Venturi Nozzle
7	Classical Venturi Tube with "as cast" convergent section
8	Classical Venturi Tube with machined convergent section
9	Classical Venturi Tube with rough-welded sheet-iron convergent section

5.4 Calibrated flow elements

If no calibration shall be considered (standard ISO 5167 calculation) the “discharge coefficient 1” has to be set to zero.

PGINPUT.TXT

```

0.           ,'= discharge coefficient 1 from calibration.0NO calibration.....[-]'
0.6255      ,'= discharge coefficient 2 from calibration.....[-]'
0.62345D5   ,'= reynoldsnumber 1 from calibration with pipe diameter.....[-]'
0.62345D7   ,'= reynoldsnumber 2 from calibration with pipe diameter.....[-]'
    
```

If calibration shall be considered a linear interpolation will be made between the given discharge coefficients and the output will include a remark with the deviation of the calibrated flow to standard ISO 5167 calculation.

PGRESULT.TXT

```

Flow Element Diameter 123.05 mm (122.90 mm at 8.33 degC Steel 5)
Pipe Diameter         202.64 mm (202.50 mm at 22.30 degC Steel 1)
Diameter Ratio        0.6072
Pressure Difference Across Flow Element 432.00 mbar = 6.27 psi

Calibrated Discharge Coefficient
Calibration Differs from ISO standard formulae by 3.40 %

  Mass Flow  alpha  Flow C Discharge  Expansion RE Reynolds  Kinematic  Mach
            Coefficient Coefficient  Factor #  (dPipe)  Viscosity
-----+-----+-----+-----+-----+-----+-----+
18.577 kg/s  0.67348  0.62604  0.99877  0.76149E+07  0.24551E-06 m2/s  0.0526
Orifice with d&d/2 Tapping
ISO5167-2003 for Flow Calculation
    
```

5.5 Temperature correction for flow elements

PGINPUT.TXT

```

11      ,'= pipe material 10NOcorr 11steel1 12steel2 13steel3 14steel4 15steel5....[-]'
...
15      ,'= flow element material 16steel6 17SnBz4 18E-Cu 19Rg9 20Ms63 21Ni 22HaC..[-]'
    
```

10	No Correction	take diameter as actual				
		Material-No.	DIN-term			Material-No. DIN-term
11	Steel I	1.0037	St 37 - 2	14	Steel IV	1.3355 S 18-0-1
		1.0038	R ST 37 - 2			1.3922 X 7 Cr 14
		1.0254	St 37.0			1.4001 X 6 Cr Al 13
		1.0305	St 35.8			1.4002 X 10 Cr 17
		1.0308	St 35			1.4006 X 10 Cr 13
		1.0309	St 35.4			1.4016 X 8 Cr 17
		1.0345	H I			1.4021 X 20 Cr 13
		1.0356	TT St 35			1.4034 X 46 Cr 13
		1.0402	C 22			1.4104 X 12 Cr Mo S 17
		1.0405	St 45.8			1.4120 X 12 Cr Mo 13
		1.0425	H II			1.4510 X 8 Cr Ti 17
		1.0435	H III			1.4713 X 10 Cr Al 7
		1.0445	H IV			1.4717 Cr Al 8 5
		1.0460	C 22.8			1.4724 X 10 Cr Al 18
		1.0486	St E 285			1.4742 X 10 Cr Al 24
		1.0505	St E 315			1.4762 Cr Al 25 5
		1.1151	Ck 22			1.4765 X 20 Cr Mo V 12 1
		1.1191	Ck 45			1.4922 12 Cr Mo V 12 1
		1.5415	15 Mo 3			1.7362 12 Cr Mo 19 5
		1.5423	16 Mo 5			1.7386 X 12 Cr Mo 9 1
		1.6918	15 Mn Ni Mo V 5 3			
		1.6919	11 Ni Mn Cr Mo 5 5			
		1.7335	13 Cr Mo 4 4			
		1.8900	St E 380			
		1.8902	St E 420			
		1.8905	St E 460			
12	Steel II	1.0437	19 Mn 6	15	Steel V	1.4301 X 5 Cr Ni 18 10
		1.0485	21 Mn 6			1.4401 X 5 Cr Ni Mo 17 12 2
		1.0562	St E 355			1.4541 X 6 Cr Ni Ti 18 10
		1.1169	20 Mn 6			1.4550 X 6 Cr Ni Nb 18 19
		1.5141	53 Mn Si 4			1.4571 X 6 Cr Ni Mo Ti 17 12 2
		1.5403	17 Mn Mo V 6 4			1.4580 X 6 Cr Ni Mo Nb 17 12 2
		1.6210	15 Mn Ni 6 3			1.4910 X 3 Cr Ni Mo N 17 13
		1.6310	20 Mn Mo Ni 5 5			1.4919 X 6 Cr Ni Mo N 7 13
		1.6311	20 Mn Mo Ni 4 5			1.4948 X 6 Cr Ni 18 11
		1.6368	15 Ni Cu Mo Nb 5			1.4949 X 3 Cr Ni N 18 11
		1.6751	22 Ni Mo Cr 3 7			1.4961 X 8 Cr Ni Nb 16 13
		1.7715	14 Mo V 6 3			1.4981 X 8 Cr Ni Mo Nb 16 16
		1.8812	15 Mn Mo V 5 2			1.4988 X 8 Cr Ni Mo V Nb 16 13
		1.8815	15 Mn Mo V 6 3			1.6903 X 10 Cr Ni Ti 18 10
		1.8817	17 Mn Mo V 6 4			1.5152 X 40 Mn Cr 22
13	Steel III	1.0481	17 Mn 4	16	Steel VI	1.5152 X 40 Mn Cr 22
		1.0482	19 Mn 5			
		1.5662	X 8 Ni 9			
		1.7033	34 Cr 4			
		1.7220	34 Cr Mo 4			
		1.7380	10 Cr Mo 9 10			
		1.7779	20 Cr Mo V 13 5			
		1.8075	10 Cr Si Mo V 7			
				17	Bronze	SnBz4
				18	Copper	E-Cu
				19	Copper	Rg9
				20	Brass	Ms63
				21	Nickel	
				22	Hastelloy C	

5.6 Assigning Components

The codes do not cover all components found in gas analysis. Progas follows the assignment below.

Caloric Properties

nC4H10	= nC4H10 + SO2
nC5H12	= nC5H12 + neoC5H12 + C6H6 + cC5H10
C6H14	= C6H14 + C7H8 + cC6H12 + CH3C5H9 + 2,2iC6H14 + 2,3iC6H14
C7H16	= C7H16 + o-C8H10 + CH3C6H11

Transport Properties

CH4	= CH4 + H2 + H2O + H2S
N2	= N2 + Ar + He + O2 + CO
nC4H10	= nC4H10 + SO2
nC5H12	= nC5H12 + neoC5H12 + C6H6 + cC5H10
C6H14	= C6H14 + C7H8 + cC6H12 + CH3C5H9 + 2,2iC6H14 + 2,3iC6H14
C7H16	= C7H16 + C8H10 + CH4C6H11
C8H18	= C8H18 + C9H20 + C10H22

The density is calculated with the compression factor found by the reduced number of components, however with the true gas constant from all components.

$$\rho_{FG} = \frac{1}{R_{FG}} \cdot \frac{p_{FG}}{z_{FG} \cdot T_{FG}} = \frac{M_{FG}}{R} \cdot \frac{p_{FG}}{z_{FG} \cdot T_{FG}}$$

ρ_{FG}	Actual density
R_{FG}	Specific gas constant
p_{FG}	Actual absolute pressure
T_{FG}	Actual thermodynamic temperature
z_{FG}	Actual compression factor according to AGA8-DC92
M_{FG}	Molar mass
R	Universal gas constant: 8.31451kJ/(kmol*K)

5.7 Overrange

The tested range for the code is given below. Any over-range will be displayed, and most probably the program will run through and set a remark in the output file. Results should still be suitable especially for low pressures with sufficient distance to condensation line, and represent the best available knowledge to date.

Range for pressure	0bar	...	650bar
Range for temperature	225K (-48°C)	...	350K (77°C)

Ranges for the analysis (Mole %)	normal	expanded
Methane	min45%	all
Carbon dioxide	max30%	all
Nitrogen	max50%	All
Ethane	max10%	All
Propane	max 4%	max 12%
Butanes	max 1%	max 6%
Pentanes	max 0.3%	max 4%
Hexanes plus	max 0.2%	max dew point
Helium	max 0.2%	max 3%
Hydrogen	none	all
Carbon monoxide	none	max 3%
Argon	none	max 1%
Oxygen	none	max 21%
Water	max 0.05%	max dew point
Hydrogen Sulfide	max 0.02%	all

6 Output File pgregresult.txt

PGRESULT.TXT

```

PROGAS (Version 15-Mar-2007) Calculation for Mixtures of Real Gases 20-Apr-2008 12:43:49
GAS 4 ISO 20765-1 2005 (E)

Actual Gas Conditions
Pressure      100.00 bar a =1450.38 psia
Temperature   76.85 degC = 170.33 degF

Sum of Given Gas Composition = 100.0000 Mol%

Results
Mol%   Vol%   Wght%
Hydrogen.....H2      9.5000  9.5310  1.1059
Helium.....He       0.0200  0.0201  0.0046
Water Vapor.....H2O  0.0100  0.0093  0.0104
Carbon Monoxide.....CO 1.0000  1.0020  1.6175
Nitrogen.....N2     10.0000 10.0216 16.1769
Oxygen.....O2       0.0100  0.0100  0.0185
Hydrogen Sulfide.....H2S 0.0100  0.0099  0.0197
Argon.....Ar        0.0100  0.0100  0.0231
Carbon Dioxide.....CO2 1.6000  1.5935  4.0663
Methane.....CH4     73.5000 73.5185 68.0926
Ethane.....C2H6     3.3000  3.2757  5.7303
Propane.....C3H8    0.7400  0.7263  1.8844
iso-Butane.....i-C4H10 0.0800  0.0768  0.2685
n-Butane.....n-C4H10 0.0800  0.0768  0.2685
neo-Pentane.....neo-C5H12 0.0000  0.0000  0.0000
iso-Pentane.....i-C5H12 0.0400  0.0376  0.1667
n-Pentane.....n-C5H12 0.0400  0.0368  0.1667
n-Hexane.....n-C6H14 0.0200  0.0179  0.0995
n-Heptane.....n-C7H16 0.0100  0.0083  0.0579
n-Octane.....n-C8H18 0.0100  0.0074  0.0660
n-Nonane.....n-C9H20 0.0100  0.0061  0.0741
n-Decane.....n-C10H22 0.0100  0.0044  0.0822
Sulfur Dioxide.....SO2 0.0000  0.0000  0.0000
Cyclopentane.....c-C5H10 0.0000  0.0000  0.0000
Cyclohexane.....c-C6H12 0.0000  0.0000  0.0000
    
```

Methylcyclopentane.....CH3-C5H9	0.0000	0.0000	0.0000				
Methylcyclohexane.....CH3-C6H11	0.0000	0.0000	0.0000				
2,2-Dimethylbutane..2,2-i-C6H14	0.0000	0.0000	0.0000				
2,3-Dimethylbutane..2,3-i-C6H14	0.0000	0.0000	0.0000				
Benzene.....C6H6	0.0000	0.0000	0.0000				
Toluene.....C7H8	0.0000	0.0000	0.0000				
o-xylene.....o-C8H10	0.0000	0.0000	0.0000				
Sum	100.000	100.000	100.000				
Ultimate Analysis in Weight%							
C=59.9415 H=19.9273 O= 3.9081 N=16.1769 S= 0.0185 HE= 0.0046 AR= 0.0231							
C+H+O+N+S+HE+AR = 100.0001							
Molar Mass = 17.3170 kg/kmol							
Gas Constant = 480.135 J/(kg*K)							
Low Heat Value = 39.729 MJ/kg = 17081. BTU/lb							
High Heat Value = 44.185 MJ/kg = 18996. BTU/lb							
Pressure	1.013bar	1.013bar	1.013bar	14.73psi	Actual		
Temperature	0. degC	15. degC	25. degC	60. degF	Actual		
-----+-----+-----+-----+-----+							
Low Heat Value	MJ/m3	30.755	29.144	28.161	29.155 2480.543		
Low Heat Value	BTU/ft3	825.4	782.2	755.8	782.5 66575.3		
High Heat Value	MJ/m3	34.204	32.412	31.319	32.425 2758.736		
High Heat Value	BTU/ft3	918.0	869.9	840.6	870.2 74041.7		
Density	kg/m3	0.7741	0.7336	0.7088	0.7338 62.4360		
Density	lb/ft3	0.0483	0.0458	0.0443	0.0458 3.8979		
Relative Density		0.5987	0.5986	0.5985	0.5986		
Compression Factor		0.99803	0.99839	0.99859	0.99840 0.95309		
Inner Energy	kJ/kg	-182.385	-159.342	-143.749	-158.483 -106.063		
Enthalpy	kJ/kg	-51.494	-21.214	-0.799	-20.087 54.101		
Entropy	kJ/(kg*K)	-0.1796	-0.0716	-0.0020	-0.0688 -1.9967		
Heat Capacity cp	kJ/(kg*K)	2.0058	2.0321	2.0512	2.0331 2.5087		
Heat Capacity cv	kJ/(kg*K)	1.5206	1.5475	1.5671	1.5486 1.7374		
Isentropic Exponent		1.3165	1.3110	1.3071	1.3108 1.4123		
Joule Thomson Coeff.	K/bar	0.4627	0.4137	0.3845	0.4120 0.1996		
Speed of Sound	m/s	415.105	425.537	432.263	425.915 475.610		
Dynamic Viscosity	Pa*s*E-6	10.954	11.477	11.821	11.496 15.329		
HeatCircuitCapacityW/	(m*K)	0.0286	0.0306	0.0320	0.0307 0.0462		
ISO6976-1995 for Molar Mass & Calorific Values @0degC							
ISO 20765-1 2005 for Thermodynamic Properties							
Flow Element Diameter	123.05 mm	(122.90 mm at	8.33 degC	Steel 5)			
Pipe Diameter	202.64 mm	(202.50 mm at	22.30 degC	Steel 1)			
Diameter Ratio	0.6072						
Pressure Difference Across Flow Element	432.00 mbar	=	6.27 psi				
Mass Flow	alpha	Flow C	Discharge	Expansion RE	Reynolds	Kinematic	Mach
	Coefficient	Coefficient	Factor	#	(dPipe)	Viscosity	
-----+-----+-----+-----+-----+							
17.966 kg/s	0.65133	0.60544	0.99877	0.73644E+07	0.24551E-06	m2/s	0.0509
Orifice with d&d/2 Tapping							
ISO5167-2003 for Flow Calculation							
Application developed by Axel Ebert, Germany & Switzerland							

6.1 Ultimate analysis

The ultimate analysis given in weight % is suitable for manual mixture calculations.

[PGRESULT.TXT](#)

Ultimate Analysis in Weight%
C=59.9415 H=19.9273 O= 3.9081 N=16.1769 S= 0.0185 HE= 0.0046 AR= 0.0231
C+H+O+N+S+HE+AR = 100.0001

6.2 Enthalpy and Entropy in heat balance calculations

Enthalpy and entropy are always differences to certain reference conditions. PROGAS calculates in reference to 1.01325bar and 25°C of ideal gas, and enthalpy and entropy would then have the value of zero. Results in the output file are always for the real gas mixture. The output file contains the values for the actual conditions as well as for the most common reference conditions, so the needed differences can be determined easily.

For example in a gas turbine heat balance calculation the reference conditions of air, exhaust gas and heat value are usually 0°C & 1.01325bar. In this case the fuel gas enthalpy and entropy to be considered is the difference between the actual conditions and 0°C & 1.01325bar, in the example below:

fuel gas enthalpy: 54.101 kJ/kg - (-51.494 kJ/kg) = 105.595 kJ/kg

fuel gas entropy: -1.9967 kJ/ (kg*K) - (-0.1796 kJ/ (kg*K)) = -1.8171 kJ/ (kg*K)

[PGRESULT.TXT](#)

Pressure		1.013bar	1.013bar	1.013bar	14.73psi	Actual
Temperature		0. degC	15. degC	25. degC	60. degF	Actual
=====+						
Density	kg/m3	0.7741	0.7336	0.7088	0.7338	62.4360
Compression Factor		0.99803	0.99839	0.99859	0.99840	0.95309
Inner Energy	kJ/kg	-182.385	-159.342	-143.749	-158.483	-106.063
Enthalpy	kJ/kg	-51.494	-21.214	-0.799	-20.087	54.101
Entropy	kJ/ (kg*K)	-0.1796	-0.0716	-0.0020	-0.0688	-1.9967

To calculate the relevant heat value at 0°C before/ after combustion the relevant data file has to be selected in pginput.txt, see 5.2

6.3 Validation

ISO 20765 is state of the art calculation for real natural gas mixtures and requires a large amount of processing. A manual check of the results is impossible. However the tool can be validated versus the published example calculations provided in Annex G of ISO 20765-1:2005

The example above meets the therein published numbers for Gas 4 at 10 MPa and 350 K. I have chosen this gas because it contains all 21 components used in the code. The results can be directly compared, with exception of entropy, because a different reference is used. To validate entropy it is necessary to run 2 calculations and compare the differences in entropy. Below is the result for Gas 4 at 5 MPa and 290 K.

[PGRESULT.TXT](#)

Pressure		1.013bar	1.013bar	1.013bar	14.73psi	Actual
Temperature		0. degC	15. degC	25. degC	60. degF	Actual
=====+						
Density	kg/m3	0.7741	0.7336	0.7088	0.7338	38.7001
Density	lb/ft3	0.0483	0.0458	0.0443	0.0458	2.4160
Relative Density		0.5987	0.5986	0.5985	0.5986	
Compression Factor		0.99803	0.99839	0.99859	0.99840	0.92789
Inner Energy	kJ/kg	-182.385	-159.342	-143.749	-158.483	-187.952
Enthalpy	kJ/kg	-51.494	-21.214	-0.799	-20.087	-58.754
Entropy	kJ/ (kg*K)	-0.1796	-0.0716	-0.0020	-0.0688	-2.0377

The entropy difference from 10 MPa 350K to 5 MPa 290 K is:

PROGAS -1.9967 kJ/ (kg*K) - (-2.0377 kJ/ (kg*K)) = 0.041 kJ/ (kg*K)

ISO 20765 -1.5311 kJ/ (kg*K) - (-1.5721 kJ/ (kg*K)) = 0.041 kJ/ (kg*K)

Heat values and flow calculations have been validated and can be checked with published sample calculations or little manual effort. For transport properties there are no sample calculations published, but the results have been checked with another proprietary tool (GASCALC)

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