```
butane              !short name
106-97-8            !CAS number
n-butane            !full name
CH3-2(CH2)-CH3      !chemical formula {C4H10}
R-600               !synonym
58.1222             !molecular weight [g/mol]
134.895             !triple point temperature [K]
272.660             !normal boiling point [K]
425.125             !critical temperature [K]
3796.0              !critical pressure [kPa]
3.922769613         !critical density [mol/L]
0.201               !acentric factor
0.05                !dipole moment [Debye]
IIR                 !default reference state
8.0                 !version number
1011                !UN Number
n-alkane            !family
2877.40             !heating value (gross or superior) [kJ/mol]
```

```
! compiled by M. McLinden, NIST Physical and Chemical Properties Division, Boulder, Colorado
! 02-01-96  MM, original version
! 03-18-96  MM, add transport correlations compiled by S.A. Klein
! 06-17-96  MM, add thermal conductivity coefficients fitted by S.A. Klein
! 07-08-96  MM, replace temporary Cp0 with function of Younglove and Ely
! 10-03-96  MM, add surface tension fit
! 10-17-96  MM, add thermal conductivity model of Younglove and Ely
! 10-18-96  MM, missing constant in dilute-gas viscosity model
! 02-20-97  MM, add default reference state
! 02-21-97  MM, put viscosity model into revised VS2 format
! 02-26-97  MM, add version number and pointer to visc critical enhancement (both future use)
! 03-06-97  MM, modify ECS-transport to new format
! 03-25-97  MM, set Psi,Chi coeff in ECS-transport to 1,0 pending refit of data
! 08-21-97  MM, purge exponentials from values read by GUI (e.g. model limits)
! 10-24-97  MM, read in f_int term in Eucken correlation in ECS method for t.c.
!               change reference fluid EOS for ECS-transport from BWR to FEQ
! 03-24-98 EWL, set max density to triple-point density (until melting line implemented)
! 11-13-98 EWL, update format to version 6.1
! 11-18-98 EWL, add equation of state of Polt et al. (1992)
! 10-14-99 EWL, update L-J parameters
! 11-01-99 EWL, add Span 12 term short equation of state
! 11-10-99 EWL, add extra digits to melting equation to get ptp at ttp
! 11-22-99 EWL, change ECS reference fluid to nitrogen
! 01-21-00 EWL, change max density of transport eqs. to match eos
! 03-20-00 EWL, change max density to the density at p=2*pmax along melting line
! 07-17-00 EWL, add Vogel viscosity equation
! 03-30-01 MLH, added Perkins et al. thermal conductivity equation (2001)
! 06-01-01 EWL, add Miyamoto and Watanabe equation
! 07-07-04 AHH, update dipole moment
! 08-05-04 EWL, add Harvey and Lemmon dielectric correlation
! 09-02-04 EWL, add Buecker and Wagner equation
! 10-13-04 MLH, add family
! 08-08-05 EWL, Ptrp in melting line equation changed slightly to match EOS at Ttrp
! 12-02-06 MLH, update LJ in ECS
! 03-05-07 MLH, added VS4 model
! 09-13-10 EWL, replace ancillary equations
! 10-21-10 EWL, increase upper pressure limit to 200 MPa based on data of Miyamoto (2008)
! 10-21-10 MLH, revised upper limit of pressure on vis. and therm. cond. to 200 MPa
```

```
#EOS               !equation of state specification
FEQ  Helmholtz equation of state for butane of Buecker and Wagner (2006).
?LITERATURE REFERENCE \
?Buecker, D. and Wagner, W.,
? "Reference Equations of State for the Thermodynamic Properties of Fluid
? Phase n-Butane and Isobutane,"
? J. Phys. Chem. Ref. Data, 35(2):929-1019, 2006.
?\
?The uncertainties in density are 0.02% at temperatures below 340 K and
?pressures below 12 MPa (both liquid and vapor states), 0.1% at temperatures
?below 270 K and pressures above 12 MPa, 0.2% between 340 and 515 K at
?pressures less than 0.6 MPa, and 0.4% elsewhere.  Above the upper pressure
?limit of 69 MPa as given in the original formulation, new data up to 200 MPa
?show that the uncertainty in density is 0.3%.  In the critical region,
?deviations in pressure are 0.5%.  At temperatures above 500 K, the
?uncertainties in density increase up to 1%.  Uncertainties in heat capacities
?are typically 1%, rising to 5% in the critical region and at pressures above
?30 MPa. Uncertainties in the speed of sound are typically 0.5%, rising to 1%
?at temperatures below 200 K and to 4% in a large area around the critical
?point.
?\
!end of info section
134.895            !lower temperature limit [K]
575.0              !upper temperature limit [K]
200000.0           !upper pressure limit [kPa]
13.86              !maximum density [mol/L]
CPP                                  !pointer to Cp0 model
58.1222                              !molecular weight [g/mol]
134.895                              !triple point temperature [K]
0.000653                             !pressure at triple point [kPa]
12.645                               !density at triple point [mol/L]
272.660                              !normal boiling point temperature [K]
0.201                                !acentric factor
425.125      3796.0       3.922769613  !Tc [K], pc [kPa], rhoc [mol/L]
425.125                   3.922769613  !reducing parameters [K, mol/L]
8.314472                             !gas constant [J/mol-K]
      23  4      2 12       0  0      !# terms, # coeff/term for:  "normal"
terms, critical, spare
 .25536998241635D+01    0.5    1.   0  !a(i),t(i),d(i),l(i)
-.44585951806696D+01    1.0    1.   0
 .82425886369063D+00    1.5    1.   0
 .11215007011442D+00    0.0    2.   0
-.35910933680333D-01    0.5    3.   0
 .16790508518103D-01    0.5    4.   0
 .32734072508724D-01    0.75   4.   0
 .95571232982005D+00    2.0    1.   1
-.10003385753419D+01    2.5    1.   1
 .85581548803855D-01    2.5    2.   1
-.25147918369616D-01    1.5    7.   1
-.15202958578918D-02    1.0    8.   1
 .47060682326420D-02    1.5    8.   1
-.97845414174006D-01    4.0    1.   2
-.48317904158760D-01    7.0    2.   2
 .17841271865468D+00    3.0    3.   2
 .18173836739334D-01    7.0    3.   2
-.11399068074953D+00    3.0    4.   2
 .19329896666669D-01    1.0    5.   2
 .11575877401010D-02    6.0    5.   2
 .15253808698116D-03    0.0   10.   2
-.43688558458471D-01    6.0    2.   3
-.82403190629989D-02   13.0    6.   3
-.28390056949441D-01    2.0    1. 2 2  -10.  -150.  1.16  .85  0. 0. 0.
 .14904666224681D-02    0.0    2. 2 2  -10.  -200.  1.13  1.   0. 0. 0.
```

```
#AUX               !auxiliary model specification
CPP  ideal gas heat capacity function
?LITERATURE REFERENCE \
?see Buecker and Wagner EOS for reference
?\
!end of info section
134.895            !lower temperature limit [K]
575.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1.0          8.314472                  !reducing parameters for T, Cp0
  1   4     0  0    0  0  0            !Nterms:  polynomial, exponential, cosh,
sinh
 4.24680487        0.00000
 5.54913289      329.40404
 11.4648996     1420.17366
 7.59987584     2113.08938
 9.66033239     4240.85730
```

```
@EOS               !equation of state specification
FEK  Helmholtz equation of state for butane of Kunz and Wagner (2004).
?LITERATURE REFERENCE \
?Kunz, O., Klimeck, R., Wagner, W., Jaeschke, M.
? "The GERG-2004 Wide-Range Equation of State for Natural Gases
? and Other Mixtures," GERG Technical Monograph 15,
? Fortschritt-Berichte VDI, VDI-Verlag, Düsseldorf, 2007.
?\
!end of info section
134.895            !lower temperature limit [K]
575.0              !upper temperature limit [K]
69000.0            !upper pressure limit [kPa]
13.2               !maximum density [mol/L]
PHK                                    !pointer to Cp0 model
58.1222                                !molecular weight [g/mol]
134.895                                !triple point temperature [K]
1.                                     !pressure at triple point [kPa]
1.                                     !density at triple point [mol/L]
272.62                                 !normal boiling point temperature [K]
 0.2038                                !acentric factor
425.125      3830.3      3.920016792   !Tc [K], pc [kPa], rhoc [mol/L]
425.125                  3.920016792   !reducing parameters [K, mol/L]
8.314472                               !gas constant [J/mol-K]
  12  4      0  0      0  0            !# terms, # coeff/term for:  "normal"
terms, critical, spare
 0.10626277411455d1     0.250  1.  0
-0.28620951828350d1     1.125  1.  0
 0.88738233403777       1.500  1.  0
-0.12570581155345       1.375  2.  0
 0.10286308708106       0.250  3.  0
 0.25358040602654d-3    0.875  7.  0
 0.32325200233982       0.625  2.  1
-0.37950761057432d-1    1.750  5.  1
-0.32534802014452       3.625  1.  2
-0.79050969051011d-1    3.625  4.  2
-0.20636720547775d-1    14.5   3.  3
 0.57053809334750d-2    12.0   4.  3
```

```
#AUX               !auxiliary model specification
PHK  Helmholtz form for the ideal-gas state for butane of Kunz and Wagner
(2004).
?LITERATURE REFERENCE \
?Kunz, O., Klimeck, R., Wagner, W., Jaeschke, M.
? "The GERG-2004 Wide-Range Equation of State for Natural Gases
? and Other Mixtures," GERG Technical Monograph 15,
? Fortschritt-Berichte VDI, VDI-Verlag, Düsseldorf, 2007.
?\
!end of info section
0.                 !lower temperature limit [K]
1000.0             !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1 2  0  2 2  0 0 0 !Nterms:  ai*log(tau**ti); ai*tau**ti; ai*log(1-
exp(bi*tau)); cosh; sinh
    3.33944      1.             !ai, ti for [ai*log(tau**ti)] terms
   20.884143364  0.             !aj, ti for [ai*tau**ti] terms
  -91.638478026  1.
   -6.89406      0.43195766     !aj, ti for cosh and sinh terms
  -14.7824       2.124516319
    9.44893      1.101487798
   24.4618       4.502440459
```

```
#AUX               !auxiliary model specification
PH0  Helmholtz form for the ideal-gas state
?LITERATURE REFERENCE \
?\
!end of info section
134.895            !lower temperature limit [K]
575.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1 2  4  0 0  0 0 0 !Nterms:  ai*log(tau**ti); ai*tau**ti; ai*log(1-exp(bi*tau))
 3.24680487         1.             !ai, ti for [ai*log(tau**ti)] terms
12.54882924         0.             !aj, ti for [ai*tau**ti] terms
-5.46976878         1.
 5.54913289        -0.7748404445   !aj, ti for [ai*log(1-exp(ti*tau)] terms
 11.4648996        -3.3406025522
 7.59987584        -4.9705130961
 9.66033239        -9.9755537783
```

```
@EOS                !equation of state specification
FE1  Helmholtz equation of state for butane of Miyamoto and Watanabe (2001).
?LITERATURE REFERENCE \
?Miyamoto, H. and Watanabe, K.
? "A Thermodynamic Property Model for Fluid-Phase n-Butane,"
? Int. J. Thermophys., 22(2):459-475, 2001.
?\
?The uncertainties of the equation of state are approximately 0.2%
?in density, 1% in heat capacity, 1% in the speed of sound, and
?0.2% in vapor pressure, except in the critical region.
?\
!end of info section
134.87              !lower temperature limit [K]
589.0               !upper temperature limit [K]
69000               !upper pressure limit [kPa]
13.15               !maximum density [mol/L]
CP1                                 !pointer to Cp0 model
58.1222                             !molecular weight [g/mol]
134.87                              !triple point temperature [K]
0.000688                            !pressure at triple point [kPa]
12.652                              !density at triple point [mol/L]
272.6                               !normal boiling point temperature [K]
0.2                                 !acentric factor
425.125      3796.0       3.92001679   !Tc [K], pc [kPa], rhoc [mol/L]
425.125                   3.92001679   !reducing parameters [K, mol/L]
8.314472                            !gas constant [J/mol-K]
      19  4      0  0       0  0       !# terms, # coeff/term for:  "normal"
terms, critical, spare
 2.952054E-01  -0.25    1.0   0        !a(i),t(i),d(i),l(i)
-1.326360E+00   1.50    1.0   0
-2.031317E-03  -0.75    2.0   0
 2.240301E-01   0.00    2.0   0
-3.635425E-02   1.25    3.0   0
 1.905841E-03   1.50    5.0   0
 7.409154E-05   0.50    8.0   0
-1.401175E-06   2.50    8.0   0
-2.492172E+00   1.50    3.0   1
 2.386920E+00   1.75    3.0   1
 1.424009E-03  -0.25    8.0   1
-9.393388E-03   3.00    5.0   1
 2.616590E-03   3.00    6.0   1
-1.977323E-01   4.00    1.0   2
-3.809534E-02   2.00    5.0   2
 1.523948E-03  -1.00    7.0   2
-2.391345E-02   2.00    2.0   3
-9.535229E-03  19.00    3.0   3
 3.928384E-05   5.00   15.0   3
```

```
#AUX               !auxiliary model specification
CP1  ideal gas heat capacity function
?LITERATURE REFERENCE \
?Miyamoto, H. and Watanabe, K.
? "A Thermodynamic Property Model for Fluid-Phase n-Butane,"
? Int. J. Thermophys., 22(2):459-475, 2001.
?\
!end of info section
134.87             !lower temperature limit [K]
589.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1.0          8.3144720                !reducing parameters for T, Cp0
  1   4     0  0    0  0  0            !Nterms:  polynomial, exponential, cosh,
sinh
 4.240207        0.00000
 5.513671      327.55988
 7.388450     1319.06935
10.250630     4138.63184
11.061010     1864.36783
```

```
@EOS               !equation of state specification
BWR  MBWR equation of state for butane of Younglove and Ely (1987).
?LITERATURE REFERENCE \
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
?The uncertainties in density are 0.05% in the liquid, 0.4% in the vapor
?and 0.06% in the supercritical and critical regions.  The uncertainty is
?2% for heat capacities, 1% for the speed of sound in the vapor, and 2%
?for the speed of sound in the liquid.
?\
?N.B.  all temperatures on IPTS-68
?\
!end of info section
134.86             !lower temperature limit [K]
500.0              !upper temperature limit [K]
70000.0            !upper pressure limit [kPa]
13.20              !maximum density [mol/L]
CP2                                  !pointer to Cp0 model
58.1222                              !molecular weight [g/mol]
134.86                               !triple point temperature [K]
6.736d-4                             !pressure at triple point [kPa]
12.650                               !density at triple point [mol/L]
272.613                              !normal boiling point temperature [K]
0.199586                             !acentric factor
425.16       3796.        3.920      !Tc [K], pc [kPa], rhoc [mol/L]
425.16                    3.920      !reducing parameters [K, mol/L]
3.920                                !gamma
0.0831434                            !gas constant [L-bar/mol-K]
      32       1                     !Nterm, Ncoeff per term
   0.153740104603d-01  -0.160980034611d+00  -0.979782459010d+01
   0.499660674504d+03  -0.102115607687d+07   0.236032147756d-02
  -0.137475757093d+01  -0.907038733865d+03   0.385421748213d+06
  -0.349453710700d-04   0.157361122714d+00   0.102301474068d+03
   0.182335737331d-01  -0.404114307787d+01   0.187979855783d+01
   0.362088795040d+00  -0.738762248266d-02  -0.218618590563d+01
   0.118802729027d+00   0.706854198713d+06  -0.219469885796d+09
  -0.182454361268d+05   0.206790377277d+10   0.111757550145d+03
   0.558779925986d+05  -0.159579054026d+02  -0.148034214622d+07
  -0.245206328201d+00   0.218305259309d+03  -0.923990627338d-04
  -0.205267776639d+01   0.387639044820d+02
```

```
#AUX               !auxiliary model specification
CP2  ideal gas heat capacity function of Younglove and Ely
?LITERATURE REFERENCE \
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
!end of info section
134.86             !lower temperature limit [K]
500.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1.0          8.31434                   !reducing parameters for T, Cp0
  7  1    0  0    0  0  0              !Nterms:  polynomial, exponential, cosh,
sinh
  3.8802310194d+5      -3.00d0
 -1.5444296890d+5      -2.00d0
  2.8455082239d+3      -1.00d0
 -1.3491511376d+1       0.00d0
  6.6142595353d-2       1.00d0
 -2.4307965028d-5       2.00d0
  1.5044248429d-10      3.00d0
 -8.3933423467d+0    3000.d0
```

```
@EOS               !equation of state specification
FES  short Helmholtz equation of state for butane of Span and Wagner (2003).
?LITERATURE REFERENCE \
?Span, R. and Wagner, W.
? "Equations of State for Technical Applications. II. Results for Nonpolar
Fluids,"
? Int. J. Thermophys., 24(1):41-109, 2003.
?\
?The uncertainties of the equation of state are approximately 0.2% (to
?0.5% at high pressures) in density, 1% (in the vapor phase) to 2% in
?heat capacity, 1% (in the vapor phase) to 2% in the speed of sound, and
?0.2% in vapor pressure, except in the critical region.
?\
!end of info section
134.86             !lower temperature limit [K]
600.0              !upper temperature limit [K]
100000.0           !upper pressure limit [kPa]
13.20              !maximum density [mol/L]
CPS                                  !pointer to Cp0 model
58.123                               !molecular weight [g/mol]
134.86                               !triple point temperature [K]
0.00064578                           !pressure at triple point [kPa]
12.671                               !density at triple point [mol/L]
272.62                               !normal boiling point temperature [K]
0.2                                  !acentric factor
425.125      3796.0       3.9199628  !Tc [K], pc [kPa], rhoc [mol/L]
425.125                   3.9199628  !reducing parameters [K, mol/L]
8.31451                              !gas constant [J/mol-K]
      12  4      0  0       0  0     !# terms, # coeff/term for:  "normal"
terms, critical, spare
 0.106262770000E+01  0.25    1.0     0 !a(i),t(i),d(i),l(i)
-0.286209520000E+01  1.125   1.0     0
 0.887382330000E+00  1.5     1.0     0
-0.125705810000E+00  1.375   2.0     0
 0.102863090000E+00  0.25    3.0     0
 0.253580410000E-03  0.875   7.0     0
 0.323252000000E+00  0.625   2.0     1
-0.379507610000E-01  1.75    5.0     1
-0.325348020000E+00  3.625   1.0     2
-0.790509690000E-01  3.625   4.0     2
-0.206367210000E-01 14.5     3.0     3
 0.570538090000E-02 12.0     4.0     3
```

```
#AUX               !auxiliary model specification
CPS  ideal gas heat capacity function
?LITERATURE REFERENCE \
?Jaeschke, M. and Schley, P.
? "Ideal-Gas Thermodynamic Properties for Natural-Gas Applications,"
? Int. J. Thermophys., 16(6):1381-1392, 1995.
?\
!end of info section
134.86             !lower temperature limit [K]
600.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1.0          8.31451                   !reducing parameters for T, Cp0
  1  0    2  2    0  0  0              !Nterms:  polynomial, exponential, cosh,
sinh
    0.4339440E+01   0.0
    0.2324827E+06  -2.0  0.1836360E+03  -1.0  -2.0
    0.1205864E+08  -2.0  0.9031850E+03  -1.0  -2.0
    0.2071931E+07  -2.0  0.4682700E+03  -1.0  -2.0
    0.8962262E+08  -2.0  0.1914100E+04  -1.0  -2.0
```

```
@EOS               !equation of state specification
FE3  Helmholtz equation of state for butane of Polt et al. (1992).
?LITERATURE REFERENCE \
?Polt, A., Platzer, B., and Maurer, G.,
? "Parameter der thermischen Zustandsgleichung von Bender fuer 14
? mehratomige reine Stoffe,"
? Chem. Tech. (Leipzig), 44(6):216-224, 1992.
?\
!end of info section
140.0              !lower temperature limit [K]
589.0              !upper temperature limit [K]
30000.0            !upper pressure limit [kPa]
12.81              !maximum density [mol/L]
CP3                                    !pointer to Cp0 model
58.124                                 !molecular weight [g/mol]
140.0                                  !triple point temperature [K]
0.00161                                !pressure at triple point [kPa]
12.573                                 !density at triple point [mol/L]
272.62                                 !normal boiling point temperature [K]
0.1984                                 !acentric factor
425.14       3783.85      3.9192072    !Tc [K], pc [kPa], rhoc [mol/L]
425.14                    3.9192072    !reducing parameters [K, mol/L]
8.3143                                 !gas constant [J/mol-K]
      22  5      0  0       0  0       !# terms, # coeff/term for:  "normal"
terms, critical, spare
-0.504188295325d+0  3.0     0.0     0  0.0            !a(i),t(i),d(i),l(i)
 0.541067401063d+0  4.0     0.0     0  0.0
-0.760421383062d-1  5.0     0.0     0  0.0
 0.846035653528d+0  0.0     1.0     0  0.0
-0.191317317203d+1  1.0     1.0     0  0.0
 0.521441860186d+0  2.0     1.0     0  0.0
-0.783511318207d+0  3.0     1.0     0  0.0
 0.689697797175d-1  4.0     1.0     0  0.0
 0.947825461055d-1  0.0     2.0     0  0.0
-0.141401831669d+0  1.0     2.0     0  0.0
 0.382675021672d+0  2.0     2.0     0  0.0
-0.423893176684d-1  0.0     3.0     0  0.0
 0.677591792029d-1  1.0     3.0     0  0.0
 0.567943363340d-1  0.0     4.0     0  0.0
-0.131517698401d+0  1.0     4.0     0  0.0
 0.221136942526d-1  1.0     5.0     0  0.0
 0.504188295325d+0  3.0     0.0     2  1.08974964
-0.541067401063d+0  4.0     0.0     2  1.08974964
 0.760421383062d-1  5.0     0.0     2  1.08974964
-0.619109535460d-1  3.0     2.0     2  1.08974964
 0.423035373804d+0  4.0     2.0     2  1.08974964
-0.390505508895d+0  5.0     2.0     2  1.08974964
```

```
#AUX               !auxiliary model specification
CP3  ideal gas heat capacity function
?LITERATURE REFERENCE \
?Polt, A., Platzer, B., and Maurer, G.,
? "Parameter der thermischen Zustandsgleichung von Bender fuer 14
? mehratomige reine Stoffe,"
? Chem. Tech. (Leipzig), 44(6):216-224, 1992.
?\
!end of info section
140.0              !lower temperature limit [K]
589.0              !upper temperature limit [K]
0.0                !upper pressure limit [kPa]
0.0                !maximum density [mol/L]
1.0          58.124                    !reducing parameters for T, Cp0
  5  0    0  0    0  0  0              !Nterms:  polynomial, exponential, cosh,
sinh
 0.801601d+00    0.00
 0.655936d-03    1.00
 0.122770d-04    2.00
-0.165626d-07    3.00
 0.677360d-11    4.00
```

```
#TCX               !thermal conductivity model specification
TC1  pure fluid thermal conductivity model of Perkins et al. (2002).
?LITERATURE REFERENCE \
?Perkins, R.A, Ramires, M.L.V., Nieto de Castro, C.A. and Cusco, L.,
? "Measurement and Correlation of the Thermal Conductivity of Butane
? from 135 K to 600 K at Pressures to 70 MPa,"
? J. Chem. Eng. Data, 47(5):1263-1271, 2002.
?\
?Uncertainty in thermal conductivity is 3%, except in the critical region
? and dilute gas which have an uncertainty of 5%.
?\
!end of info section
134.86             !lower temperature limit [K]
600.0              !upper temperature limit [K]
200000.0           !upper pressure limit [kPa]
13.86              !maximum density [mol/L]
3   0              !# terms for dilute gas function:  numerator, denominator
425.16  1.0        !reducing parameters for T, tcx
1.62676d-3    0.00d0   !coeff, power in T
 9.75703d-4    1.00d0
 2.89887d-2    2.00d0
10  0               !# terms for background gas function:  numerator,
denominator
425.16  3.92  1.0                          !reducing par for T, rho, tcx
-3.04337d-2     0.0  1.0  0.0 !coeff, powers of T, rho, spare for future use
 4.18357d-2    1.00d0   1.00d0   0.00d0
 1.65820d-1    0.00d0   2.00d0   0.00d0
-1.47163d-1    1.00d0   2.00d0   0.00d0
-1.48144d-1    0.00d0   3.00d0   0.00d0
 1.33542d-1    1.00d0   3.00d0   0.00d0
 5.25500d-2    0.00d0   4.00d0   0.00d0
-4.85489d-2    1.00d0   4.00d0   0.00d0
-6.29367d-3    0.00d0   5.00d0   0.00d0
 6.44307d-3    1.00d0   5.00d0   0.00d0
TK3                !pointer to critical enhancement auxiliary function
```

```
#AUX               !thermal conductivity critical enhancement model
TK3  thermal conductivity critical enhancement of Perkins et al. (2002).
?LITERATURE REFERENCE \
?Perkins, R.A., Ramires, M.L.V., Castro de Nieto, C.A. and Cusco, L.,
? "Measurement and Correlation of the Thermal Conductivity of Butane
? from 135 K to 600 K at Pressures to 70 MPa,"
? J. Chem. Eng. Data, 47(5):1263-1271, 2002.
?\
!end of info section
134.86             !lower temperature limit [K]
600.0              !upper temperature limit [K]
200000.0           !upper pressure limit [kPa]
13.86              !maximum density [mol/L]
9  0  0  0         !# terms:  terms, spare, spare, spare
1.0    1.0  1.0    !reducing par for T, rho, tcx (mW/m-K)
0.630d0            !gnu (universal exponent)
1.239d0            !gamma (universal exponent)
1.03d0             !R0 (universal amplitude)
0.063d0            !z (universal exponent--not used for t.c., only viscosity)
1.00d0             !c (constant in viscosity eqn = 1/[2 - (alpha +
gamma)/(2*nu)], but often set to 1)
0.194d-9           !xi0 (amplitude) [m]
0.0496             !gam0 (amplitude) [-]
0.875350d-9        !qd_inverse (modified effective cutoff parameter) [m]
637.68             !tref (reference temperature) [K]
```

```
@TCX                !thermal conductivity model specification
TC2  pure fluid thermal conductivity model of Younglove and Ely (1987).
?LITERATURE REFERENCE \
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
?The uncertainty in thermal conductivity is 2%, except in the critical region
?which is 10%.
?\
?N.B.  all temperatures on IPTS-68
?\
!end of info section
134.86              !lower temperature limit [K]
500.0               !upper temperature limit [K]
70000.0             !upper pressure limit [kPa]
13.86               !maximum density [mol/L]
CI2                 !pointer to collision integral model
0.503103            !Lennard-Jones coefficient sigma [nm]
440.0               !Lennard-Jones coefficient epsilon/kappa [K]
 2.0352526600d-01   !const in Eq 19 = 5/16*(k*MW/1000/pi/Na)**0.5*1.0d12
 0.1530992335d+01   !dilute gas terms (Eq 27):  Gt(1)
-0.2114511021d+00   !                           Gt(2)
 0.4024170074d-02   !residual terms (Eqs 26, 28-30): Et(1)
 0.1561435847d+01
-0.6004381127d+03
-0.7547260841d-03
-0.2069676662d-01
 0.9382534978d+02
-0.1711371457d+00
 0.3647724935d+02   !Et(8)
TK2                 !pointer to critical enhancement model (follows immediately)
 0.000769608d0      !critical enhancement terms (Eqs D1-D4):  X1
13.2533d0
 0.485554d0
 1.01021d0          !X4
 9.10218d-10        !Z
 1.38054d-23        !Boltzmann's constant, k
 0.1630521851d+01   !coeff for initial density dependence of viscosity (eq 21);
Fv(1)
 0.0                !Fv(2)
 1.40               !Fv(3)
 425.16             !Fv(4)
-0.2724386845d+02   !coefficients for residual viscosity, eqs (22 - 25)
 0.8012766611d+03   !Ev(2)  (the viscosity is also used in conductivity
correlation)
 0.2503978646d+02   !Ev(3)
-0.1309704275d+05   !Ev(4)
-0.8313305258d-01   !Ev(5)
 0.6636975027d+02   !Ev(6)
 0.9849317662d+04   !Ev(7)
```

```
#ETA                !viscosity model specification
VS1  pure fluid viscosity model of Vogel et al. (1999).
?LITERATURE REFERENCE \
?Vogel, E., Kuechenmeister, C., and Bich, E.,
? "Viscosity for n-Butane in the Fluid Region,"
? High Temp. - High Pressures, 31(2):173-186, 1999.
?\
?The uncertainty in viscosity varies from 0.4% in the dilute gas between
?room temperature and 600 K, to 3.0% over the rest of the fluid surface.
?\
!end of info section
134.86              !lower temperature limit [K]
500.0               !upper temperature limit [K]
200000.0            !upper pressure limit [kPa]
13.86               !maximum density [mol/L]
1                   !number of terms associated with dilute-gas function
CI1                 !pointer to reduced effective collision cross-section model
0.57335             !Lennard-Jones coefficient sigma [nm]
280.51              !Lennard-Jones coefficient epsilon/kappa [K]
1.0    1.0          !reducing parameters for T, eta
0.1628213  0.50d0   !Chapman-Enskog term
9                   !number of terms for initial density dependence
 280.51       0.1135034    !reducing parameters for T (= eps/k), etaB2 (=
0.6022137*sigma**3)
-19.572881d0       0.0     !coeff, power in T* = T/(eps/k)
 219.73999d0      -0.25
-1015.3226d0      -0.5
 2471.01251d0     -0.75
-3375.1717d0      -1.0
 2491.6597d0      -1.25
-787.26086d0      -1.5
 14.085455d0      -2.5
-0.34664158d0     -5.5
2 13 1 2 0 0        !# resid terms:  close-packed density;  simple poly;
numerator of rational poly; denominator of rat. poly; numerator of exponential;
denominator of exponential
425.125    3.92       1.0           !reducing parameters for T, rho, eta
 2.30873963359      0.0    0.00  0.00  0
 2.03404037254      0.5    0.00  0.00  0
-54.7737770846      0.0    2.00  0.00  0
 58.0898623034     -1.0    2.00  0.00  0
 0                 -2.0    2.00  0.00  0
 35.2658446259      0.0    3.00  0.00  0
-39.6682203832     -1.0    3.00  0.00  0
 0                 -2.0    3.00  0.00  0
-1.83729542151      0.0    4.00  0.00  0
 0                 -1.0    4.00  0.00  0
 0                 -2.0    4.00  0.00  0
-0.833262985358     0.0    5.00  0.00  0
 1.93837020663     -1.0    5.00  0.00  0
 0                 -2.0    5.00  0.00  0
-188.075903903      0.0    1.00 -1.00  0
 188.075903903      0.0    1.00  0.00  0
 1.                 0.0    0.00  1.00  0
-1.                 0.0    1.00  0.00  0
NUL                 !pointer to critical enhancement auxiliary function (none
used)
```

```
#AUX               !collision integral specification
CI1  collision integral model of Vogel et al. (1999).
?LITERATURE REFERENCE \
?Vogel, E., Kuechenmeister, C., and Bich, E.,
? "Viscosity for n-Butane in the Fluid Region,"
? High Temp. - High Pressures, 31(2):173-186, 1999.
?\
!end of info section
134.86             !lower temperature limit [K]
500.0              !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
3                  !number of terms
 0.17067154   0    !coeff, power of Tstar
-0.48879666   1
 0.039038856  2
```

```
@ETA                !viscosity model specification
VS2  pure fluid viscosity model of Younglove and Ely (1987).
?LITERATURE REFERENCE \
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
?The uncertainty in viscosity is 2%, except in the critical region which is 5%.
?\
?N.B.  all temperatures on IPTS-68
?\
!end of info section
134.86              !lower temperature limit [K]
500.0               !upper temperature limit [K]
70000.0             !upper pressure limit [kPa]
13.86               !maximum density [mol/L]
CI2                 !pointer to collision integral model
0.503103            !Lennard-Jones coefficient sigma [nm]
440.0               !Lennard-Jones coefficient epsilon/kappa [K]
 2.0352457000d-01   !const in Eq 19 = 5/16*(k*MW/1000/pi/Na)**0.5*1.0d12
 0.5                !exponent in Eq 19 for T
 0.1630521851d+01   !coeff for initial density dependence of viscosity (eq 21);
Fv(1)
 0.0                !Fv(2)
 1.40               !Fv(3)
 425.16             !Fv(4)
-0.2724386845d+02   !coefficients for residual viscosity, eqs (22 - 25)
 0.8012766611d+03   !Ev(2)
 0.2503978646d+02   !Ev(3)
-0.1309704275d+05   !Ev(4)
-0.8313305258d-01   !Ev(5)
 0.6636975027d+02   !Ev(6)
 0.9849317662d+04   !Ev(7)
 3.920              !Ev(8)
NUL                 !pointer to critical enhancement auxiliary function (none
used)
```

```
#AUX               !collision integral specification
CI2  collision integral model of Younglove and Ely (1987).
?LITERATURE REFERENCE \
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
?N.B.  all temperatures on IPTS-68
?\
!end of info section
134.86             !lower temperature limit [K]
500.0              !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
9                  !number of terms
 -3.0328138281     !Omega (eq 20): coeffs of {(e/kT)**((4-n)/3)}
 16.918880086      !N.B.  there is misprint in Younglove and Ely, the exponent
-37.189364917      !      is ((4-n)/3) not ((n+2)/3)
 41.288861858
-24.61592114
  8.948843096
 -1.8739245042
  0.209661014      !N.B.  wrong sign in Younglove and Ely, Table 2
 -0.009657044
```

```
@ETA                !viscosity model specification
VS4  pure fluid generalized friction theory viscosity model of Quinones-
Cisneros and Deiters (2006).
?LITERATURE REFERENCE \
? Quinones-Cisneros, S.E. and Deiters, U.K.
? "Generalization of the Friction Theory for Viscosity Modeling,"
? J. Phys. Chem. B, 110:12820-12834, 2006.
?
!end of info section
134.895             !lower temperature limit [K]
500.0               !upper temperature limit [K]
68000.0             !upper pressure limit [kPa]
13.86               !maximum density [mol/L]
4 0 0 0 0 0         !number of terms associated with dilute-gas function
NUL                 !pointer to reduced effective collision cross-section
model;not used
0.503103            !Lennard-Jones coefficient sigma [nm] (not used)
440.0               !Lennard-Jones coefficient epsilon/kappa [K] (not used)
425.125d0   1.0d0   !reducing parameters for T, eta
 0.0d0      0.5d0   !Chapman-Enskog term; not used here
 18.3983d0  0.0d0   !empirical terms for eta0
-57.1255d0  0.25d0
 49.3197d0  0.5d0
0                   !number of terms for initial density dependence; not yet
used.
-1.34110938674421d-05 -8.56587924603951d-05 -6.45720639242339d-13
!a(0),a(1),a(2)
 1.49859653515567d-04 -1.71133855507542d-04  7.37953726544736d-13
!b(0),b(1),b(2)
 3.53018109777015d-07 -1.93040375218067d-05 -1.26469933968355d-14
!c(0),c(1),c(2)
-3.63389393526204d-09 -7.73717469888952d-10  0.00000000000000d+00
!A(0),A(1),A(2)
 3.70980259815724d-08  2.07658634467549d-09  0.00000000000000d+00
!B(0),B(1),B(2)
-1.12495594619911d-07  7.66906137372152d-08  0.00000000000000d+00
!C(0),C(1),C(2)
 0.0d0                   0.0d0                   0.0d0
!D(0),D(1),D(2)
NUL                 !pointer to critical enhancement auxiliary function (none
used)
```

```
@TRN                !transport model specification
ECS  Extended Corresponding States model (Nitrogen reference);  predictive
mode.
?LITERATURE REFERENCES \
?Klein, S.A., McLinden, M.O., and Laesecke, A.,
? "An improved extended corresponding states method for estimation of
? viscosity of pure refrigerants and mixtures,"
? Int. J. Refrigeration, 20:208-217, 1997.
?\
?McLinden, M.O., Klein, S.A., and Perkins, R.A.,
? "An extended corresponding states model for the thermal conductivity
? of refrigerants and refrigerant mixtures,"
? Int. J. Refrigeration, 23:43-63, 2000.
?\
?Thermal conductivity and viscosity data used in the development of the
?extended corresponding states correlations were taken from:
?\
?Younglove, B.A. and Ely, J.F.,
? "Thermophysical properties of fluids. II. Methane, ethane, propane,
? isobutane and normal butane,"
? J. Phys. Chem. Ref. Data, 16:577-798, 1987.
?\
?the Lennard-Jones parameters are taken from:
?\
?Reid, R.C., Prausnitz, J.M., and Poling, B.E.,
? "The Properties of Gases and Liquids,"
? 4th edition, New York, McGraw-Hill Book Company, 1987.
?\
!end of info section
134.86              !lower temperature limit [K]
500.0               !upper temperature limit [K]
70000.0             !upper pressure limit [kPa]
13.86               !maximum density [mol/L]
FEQ nitrogen.fld
VS1                 !model for reference fluid viscosity
TC1                 !model for reference fluid thermal conductivity
1                   !Lennard-Jones flag (0 or 1) (0 => use estimates)
0.57335             !Lennard-Jones coefficient sigma [nm]
280.51              !Lennard-Jones coefficient epsilon/kappa [K]
1  0  0                         !number of terms in f_int term in Eucken
correlation, spare1, spare2
 1.32d-3        0.0  0.0  0.0 !coeff, power of T, spare 1, spare 2
1  0  0                         !number of terms in psi (visc shape factor):
poly,spare1,spare2
 1.0            0.0  0.0  0.0 !coeff, power of Tr, power of Dr, spare
1  0  0                         !number of terms in chi (t.c. shape factor):
poly,spare1,spare2
 1.0            0.0  0.0  0.0 !coeff, power of Tr, power of Dr, spare
NUL                           !pointer to critical enhancement auxiliary
function
```

```
#STN        !surface tension specification
ST1  surface tension model; fit of data from Calado (1978) and Coffin (1928).
?LITERATURE REFERENCE \
?Fit of data from:
?\
?Calado, J.C.G., McLure, I.A., and Soares, V.A.M.,
? "Surface tension for octafluorocyclobutane, n-butane and their mixtures
? from 233 K to 254 K, and vapour pressure, excess Gibbs function and excess
? volume for the mixture at 233 K,"
? Fluid Phase Equilibria, 2:199-213, 1978.
?\
?Coffin, C.C. and Maass, O.,
? "The preparation and physical properties of alpha-, beta- and gamma-
? butylene and normal and isobutane,"
? J. Am. Chem. Soc., 50:1427-1437, 1928.
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
1                          !number of terms in surface tension model
425.125                    !critical temperature used in fit (dummy)
 0.05418     1.26          !sigma0 and n
```

```
#DE         !dielectric constant specification
DE3  dielectric constant model of Harvey and Lemmon (2005).
?LITERATURE REFERENCE \
?Harvey, A.H. and Lemmon, E.W.
? "Method for Estimating the Dielectric Constant of Natural Gas Mixtures,"
? Int. J. Thermophys., 26(1):31-46, 2005.
?\
!end of info section
0.0                !lower temperature limit [K]
2000.0             !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
273.16 1000.0 1.0  !reducing parameters for t and d
1 2 4 0 0 0                          !number of terms in dielectric constant
model
 0.0557549       -1.    1.    0.    !coef, t exp, d exp
 20.611           0.    1.    0.
 0.020            1.    1.    0.
 66.64            0.    2.    0.
 24.44            1.    2.    0.
-7461.2           0.    3.    0.
-1983.6           1.    3.    0.
```

```
#MLT        !melting line specification
ML1  melting line model of Buecker and Wagner (2005).
?LITERATURE REFERENCE \
? see EOS for reference
?\
!end of info section
134.895            !lower temperature limit [K]
575.0              !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
134.895 0.00066566 !reducing temperature and pressure
2 0 0 0 0 0                 !number of terms in melting line equation
-558558235.4    0.          !coefficients and exponents
 558558236.4    2.206
```

```
#PS          !vapor pressure equation
PS5  vapor pressure equation of Lemmon (2010).
?LITERATURE REFERENCE \
?Lemmon, E.W., 2010.
?\
!end of info section
134.895             !lower temperature limit [K]
425.125             !upper temperature limit [K]
0.0                 !(dummy) upper pressure limit
0.0                 !(dummy) maximum density
425.125 3796.0      !reducing parameters
4 0 0 0 0 0         !number of terms in equation
-0.71897D+01   1.0 !coefficients and exponents
 0.26122D+01   1.5
-0.21729D+01   2.0
-0.27230D+01   4.5
```

```
#DL         !saturated liquid density equation
DL1  saturated liquid density equation of Lemmon (2010).
?LITERATURE REFERENCE \
?Lemmon, E.W., 2010.
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
425.125 3.922769613 !reducing parameters
4 0 0 0 0 0        !number of terms in equation
 0.52341D+01   0.44     !coefficients and exponents
-0.62011D+01   0.60
 0.36063D+01   0.76
 0.22137D+00   5.00
```

```
#DV          !saturated vapor density equation
DV3  saturated vapor density equation of Lemmon (2010).
?LITERATURE REFERENCE \
?Lemmon, E.W., 2010.
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
425.125 3.922769613 !reducing parameters
5 0 0 0 0 0        !number of terms in equation
-0.27390D+01   0.391     !coefficients and exponents
-0.57347D+01   1.14
-0.16408D+02   3.0
-0.46986D+02   6.5
-0.10090D+03  14.0
```

```
@END
c         1         2         3         4         5         6         7
8
c234567890123456789012345678901234567890123456789012345678901234567890123456789
0
```

```
#PS         !vapor pressure equation
PS5  vapor pressure equation of Buecker and Wagner (2005).
?LITERATURE REFERENCE \
?See EOS
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
425.125 3796.0     !reducing parameters
4 0 0 0 0 0                !number of terms in equation
 -7.17616903         1.0    !coefficients and exponents
  2.53635336         1.5
 -2.07532869         2.0
 -2.82241113         4.5
```

```
#DL         !saturated liquid density equation
DL1  saturated liquid density equation of Buecker and Wagner (2005).
?LITERATURE REFERENCE \
?See EOS
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
425.125 3.922769613 !reducing parameters
4 0 0 0 0 0                 !number of terms in equation
 1.97874515          0.345  !coefficients and exponents
 0.856799510         1.0
-0.341871887         1.5
 0.304337558         3.0
```

```
#DV          !saturated vapor density equation
DV6  saturated vapor density equation of Buecker and Wagner (2005).
?LITERATURE REFERENCE \
?See EOS
?\
!end of info section
134.895            !lower temperature limit [K]
425.125            !upper temperature limit [K]
0.0                !(dummy) upper pressure limit
0.0                !(dummy) maximum density
425.125 3.922769613 !reducing parameters
4 0 0 0 0 0                 !number of terms in equation
-2.07770057          1.035  !coefficients and exponents
-3.08362490          2.5
-0.485645266         9.5
-3.83167519         12.5
```