User Instructions for EES_REFPROP

REFPROP (Versions 7 and newer, http://www.nist.gov/srd/nist23.htm), developed by the National Institute of Standards and Technology, provides the most accurate thermodynamic and transport property data currently available for pure fluids and fluid mixtures. The property subroutines in these programs have been linked with an interface program called EES_REFPROP to that is callable from EES.

INSTALLATION

EES_REFPROP is provided with an installation utility that should guide the installation process. The EES_REFPROP interface package includes the following files.

EES_REFPROP.PDF	{this file in Acrobat format}
EES_REFPROP.FDL	{the interface program between EES and REFPROP versions 6 or 7}
EES_REFPROP.CHM	{help file providing user instructions for the EES_REFPROP interface}
EES_REFPROP.TXT	{a text file read by EES that sets a number of constants}
DFORRT.DLL	{a system file needed to run the EES_REFPROP.FDL program}
MSVCRTD.DLL	{a system file needed to run the EES_REFPROP.FDL program}
R134aTST.EES	{an EES test file for a pure refrigerant}
123-134a.EES	{an EES test file for calculating bubble and dew points for a mixture}
NARM_ID.EES	{an EES test file for performance of a mixed refrigerant heat pump}

The EES_REFPROP.FDL, EES_REFPROP.HLP and EES_REFPROP.TXT files should be installed in a folder within the EES32\USERLIB folder. The installation program places these files in the \USERLIB\EES_REFPROP folder. The DFORRT.DLL and MSVCRTD.DLL files will be placed in the WINNT\SYSTEM32 directory (for WINDOW NT/2000/XP) or the WINDOWS\SYSTEM directory (for WINDOWS 95). The installation program will also place instructions and example files in the \EES32\USERLIB\EES_REFPROP directory.

EES_REFPROP calls the NIST REFPROP program (version 7 or newer) to do the necessary property calculations. The file that is provided with the REFPROP program that is called by EES is REFPROP.DLL. By default, EES_REFPROP assumes that this file and the \Fluids and \Mixtures folders provided with it can be found in the C:\REFPROP, the C:\PROGRAM FILES\REFPROP or the C:\PROGRAM FILES\NIST\REFPROP directories. If the REFPROP.DLL file is not located in any of these directories, EES will display a "Select Directory" dialog the first time REFPROP is called in which you can identify the location of the REFPROP.DLL file.

The EES_REFPROP name should be visible in the Function Info dialog (Options menu) when you select the External Routines radio button. Click on the EES_REFPROP name to select it and then press the Info button to obtain user instructions from within EES.

Starting with EES version 9.547, EES will check the unit consistency of the inputs and outputs in the calls to the EES_REFPROP interface.

F-Chart Software http://fChart.com email: info@fchart.com
Box 44042 Madison, WI 53744 FAX: (608) 274-4262

INSTRUCTIONS FOR USING EES_REFPROP

The general format of a property request to EES_REFPROP is:

CALL EES_REFPROP('Fluid1+Fluid2', MODE, In1, In2, ... : Out1, Out2, ...)

EES_REFPROP will return thermodynamic property information for a specified state, which may include molecular weight, saturation property information, transport properties, fugacity or critical properties depending on the value of the parameter MODE. The required inputs and calculated outputs differ for different values of MODE as explained below.

The first argument in the EES_REFPROP Call statement identifies the fluid system which may be a pure fluid or a mixture of up to 20 components. Fluid names are ordinarily the familiar refrigerant names, e.g., R12, R134a, etc. or any mixture name previously defined within the REFPROP program, e.g., R406c. A complete list of fluid names is provided in the REFPROP and manuals. The fluid system name must be must be enclosed within single quotes. A mixture of pure components is identified by use of a plus (+ sign between the component names, e.g., 'R12+R152a'. Upper and lower case letters are treated identically. Spaces should not appear in the fluid system name. The convergence capabilities of REFPROP for mixtures in the saturation region can often be enhanced by calling a splining routine in REFPROP called SATSPLN. To invoke this call, add /S to the fluid name, e.g., 'R12+R152a/S';

The second argument, MODE, is an integer which identifies the calculations to be done and the necessary inputs and outputs. Rather than specify an integer for MODE, however, it is more convenient to use a text code in the form of an EES variable. For example, MODE=12 indicates that thermodynamic properties corresponding to specified inputs of temperature and pressure are to be calculated. It is preferable to use a variable TP (which is set to 12) rather than 12 itself for MODE. The file EES_REFPROP.TXT includes EES variables for each of the modes listed below. To make use of these codes, ensure that the EES_REFPROP.TXT file is in the \EES32\USERLIB\ subdirectory and include the following line at the top of your EES file.

$INCLUDE \EES32\USERLIB\EES_REFPROP.TXT

Each of the MODES and their associated inputs and outputs are provided below.

MODE = MW (=0)

Description: Molecular mass of a specified pure fluid or mixture
In1 = mole fraction of first component in saturated liquid (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Molecular weight
Example:

```
CALL EES_REFPROP('R32', MW : MW_R32)
```

MODE = BUBT (=1)

Description: Bubble point calculation for a given temperature
In1 = Temperature in K
In2 = mole fraction of first component in saturated liquid (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Pressure of saturated liquid in kPa
Out2 = Density of saturated liquid in kmol/m^3
Out3 = Pressure of saturated vapor in kPa
Out4 = Density of saturated vapor in kmol/m^3
Out5..OutN = Mole fractions of each component in vapor at equilibrium with the liquid
Example:

```
CALL EES_REFPROP('R32+R134a',BUBT,300 [K],0.3 : PL,DL,PV,DV,y_32,y_134a)
```

MODE = DEWT (=2)

Description: Dew point calculation for a given temperature
In1 = Temperature in K
In2 = mole fraction of first component in saturated vapor (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Pressure of saturated liquid in kPa
Out2 = Density of saturated liquid in kmol/m^3
Out3 = Pressure of saturated vapor in kPa
Out4 = Density of saturated vapor in kmol/m^3
Out5..OutN = Mole fractions of each component in liquid at equilibrium with the vapor
Example:

```
CALL EES_REFPROP('R32+R134a',DEWT,300 [K],0.3 : PL,DL,PV,DV,x_32,x_134a)
```

MODE = BUBP (=3)

Description: Bubble point calculation for a given pressure
In1 = Pressure in kPa
In2 = mole fraction of first component in saturated liquid (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Temperature of saturated liquid in K
Out2 = Density of saturated liquid in kmol/m^3
Out3 = Temperature of saturated vapor in K
Out4 = Density of saturated vapor in kmol/m^3
Out5..OutN = Mole fractions of each component in vapor at equilibrium with the liquid
Example:

```
CALL EES_REFPROP('R32+R134a',BUBP,100 [kPa],0.3 : TL,DL,TV,DV,y_32,y_134a)
```

MODE = DEWP (=4)

Description: Dew point calculation for a given pressure
In1 = Pressure in kPa
In2 = mole fraction of first component in saturated liquid (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Temperature of saturated liquid in K
Out2 = Density of saturated liquid in kmol/m^3
Out3 = Temperature of saturated vapor in K
Out4 = Density of saturated vapor in kmol/m^3
Out5..OutN = Mole fractions of each component in liquid at equilibrium with the vapor
Example:

```
CALL EES_REFPROP('R32+R134a',DEWP,100 [kPa],0.3 : PL,DL,PV,DV,y_32,y_134a)
```

MODE = TP (=12)

Description: Calculate thermodynamic properties for given temperature and pressure
In1 = Temperature in K
In2 = Pressure in kPa
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Temperature in K
Out2 = Pressure in kPa
Out3 = Density in kmol/m^3
Out4 = Specific volume in m^3/kmol
Out5 = Specific enthalpy in kJ/kmol
Out6 = Specific entropy in kJ/K-kmol
Out7 = Quality molar basis(<0 for subcooled liquid, >1 for superheated vapor)
Out8= Specific heat at constant volume (Cv) in kJ/K-kmol
Out9 = Specific heat at constant pressure (Cp) in kJ/K-kmol
Out10 = Speed of sound in m/sec (not applicable for two-phase state)
Out11 = Quality mass basis(<0 for subcooled liquid, >1 for superheated vapor)
Out12..12+N = mole fractions of the liquid phase for the N components in the mixture
Out12+N+1..Out12+2N = mole fractions of the vapor phase for the N components
Example:

```
CALL EES_REFPROP('R32+R134a',TP ,300 [K],100 [kPa],0.3 :
                                T,P,rho,v,h,s,Q,Cv,Cp,w,Qm, x_R32,x_R134a,y_R32,y_R134a)
```

MODE = TD (=13)

Description: Calculate thermodynamic properties for given temperature and density
In1 = Temperature in K
In2 = Density in kmol/m3
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP

Example:

```
CALL EES_REFPROP('R32+R134a',TD ,300 [K],0.075 [kmol/m^3],0.3 :
                        T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = TV (=14)

Description: Calculate thermodynamic properties for given temperature and specific volume
In1 = Temperature in K
In2 = Specific volume in m^3/kmol
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outtputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',TV,300 [K],13.1 [m^3/kmol],0.3 :
                        T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = TH (=15)

Description: Calculate thermodynamic properties for given temperature and specific enthalpy
In1 = Temperature in K
In2 = Specific enthalpy in kJ/kmol
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',TH ,300 [K],39200 [kJ/kmol],0.3 :
                        T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = TS (=16)

Description: Calculate thermodynamic properties for given temperature and specific entropy
In1 = Temperature in K
In2 = Specific entropy in kJ/kmol
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',TS ,300 [K],180 [kJ/kmol-K],0.3 :
                        T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = TQ (=17)

Description: Calculate thermodynamic properties for given temperature and molar quality
In1 = Temperature in K
In2 = Quality (0 for saturated liquid, 1 for saturated vapor)
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',TQ ,300 [K],0,0.3 :
                              T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = PD (=23)

Description: Calculate thermodynamic properties for given pressure and specific enthalpy
In1 = Pressure in kPa
In2 = Density in kmol/m^3
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',PD ,1000 [kPa],13.5 [kmol/m^3],0.3 :
                              T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = PH (=25)

Description: Calculate thermodynamic properties for given pressure and specific enthalpy
In1 = Pressure in kPa
In2 = Specific enthalpy in kJ/kmol
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',PH ,1000 [kPa],20000 [kJ/kmol],0.3 :
                              T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = PS (=26)

Description: Calculate thermodynamic properties for given pressure and specific entropy
In1 = Pressure in kPa
In2 = Specific entropy in kJ/K-kmol
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP

Example:

```
CALL EES_REFPROP('R32+R134a',PS ,1000 [kPa],30.0 [kJ/kmol-K],0.3 :
                                T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = PQ (=27)

Description: Calculate thermodynamic properties for given pressure and molar quality
In1 = Pressure in kPa
In2 = Quality molar basis(0 for saturated liquid, 1 for saturated vapor)
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Outputs: Same as for MODE = TP
Example:

```
CALL EES_REFPROP('R32+R134a',PQ,1000 [kPa],0,0.3 :
                                T,P,rho,v,h,s,Q,Cv,Cp,w,Qm,x_R32,x_R134a,y_R32,y_R134a)
```

MODE = ST (=70)

Description: Calculate surface tension for given saturation temperature
In1 = Temperature in K
In2 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1: surface tension of fluid or mixture in N/m
Example:

```
CALL EES_REFPROP('R32+R134a', ST, 300 [K], 0.3 : sigma)
```

MODE = FUG (=80)

Description: Calculate fugacity for given temperature and density
In1 = Temperature in K
In2 = Density in kmol/m3
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1..OutN: fugacity of each fluid in kPa
Example:

```
CALL EES_REFPROP('R32+R134a',FUG,300 [K], 0.075 [kmol/m^2], 0.3 :f_32,f_143a)
```

MODE = TRN (=90)

Description: Calculate transport properties for given temperature and density
In1 = Temperature in K
In2 = Density in kmol/m3
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Viscosity in μPa-sec
Out2 = Thermal conductivity in W/m-K

Example:
CALL EES_REFPROP('R32+R134a',TRN,300 [K],0.075 [kmol/m^3]: Visc, Cond)

MODE = DC (=95)

Description: Calculate the dielectric constant for given temperature and density
In1 = Temperature in K
In2 = Density in kmol/m3
In3 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1: dielectric constant of the fluid
Example:
CALL EES_REFPROP('Methane+Ethane',DC,300[K],0.075[kmol/m^3],0.3: DielectricConst)

MODE = CRIT (=100)

Description: Calculate critical properties
In1 = mole fraction of first component (skip for pure fluid)
...
InN = mole fraction of next to last component
Out1 = Critical temperature in K
Out2 = Critical pressure in kPa
Out3 = Critical density in kmol/m3
Example:
CALL EES_REFPROP('R32+R134a',CRIT,0.3 : Tc, Pc, rhoc)

See the online help (file EES_REFPROP.chm for more detail.)