

## User Instructions for EES\_REFPROP

REFPROP (Versions 8 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}  
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 installation program will also place instructions and example files in the \EES32\USERLIB\EES\_REFPROP directory.

EES\_REFPROP calls the NIST REFPROP program 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. Starting with EES version 10.119, the \$ConvertEESREFPROPUnits directive will automatically convert the inputs to and the outputs from the EES\_REFPROP interface to match the unit system set in EES. The /mass flag for the \$ConvertEESREFPROPUnits directive is available in EES version 10.187 or newer.

## 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 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<sup>3</sup>

Out3 = Pressure of saturated vapor in kPa

Out4 = Density of saturated vapor in kmol/m<sup>3</sup>

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<sup>3</sup>

Out3 = Pressure of saturated vapor in kPa

Out4 = Density of saturated vapor in kmol/m<sup>3</sup>

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<sup>3</sup>

Out3 = Temperature of saturated vapor in K

Out4 = Density of saturated vapor in kmol/m<sup>3</sup>

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<sup>3</sup>

Out3 = Temperature of saturated vapor in K

Out4 = Density of saturated vapor in kmol/m<sup>3</sup>

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<sup>3</sup>

Out4 = Specific volume in m<sup>3</sup>/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/m<sup>3</sup>

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<sup>3</sup>/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',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<sup>3</sup>

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/m<sup>3</sup>

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/m<sup>3</sup>

In3 = mole fraction of first component (skip for pure fluid)

...

InN = mole fraction of next to last component

Out1 = Viscosity in  $\mu$ Pa-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/m<sup>3</sup>

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/m<sup>3</sup>

Example:

```
CALL EES_REFPROP('R32+R134a',CRIT,0.3 : Tc, Pc, rhoc)
```

See the online help (file EES\_REFPROP.chm for more detail.)