

EESy Solutions

Engineering Equation Solver Newsletter

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Welcome

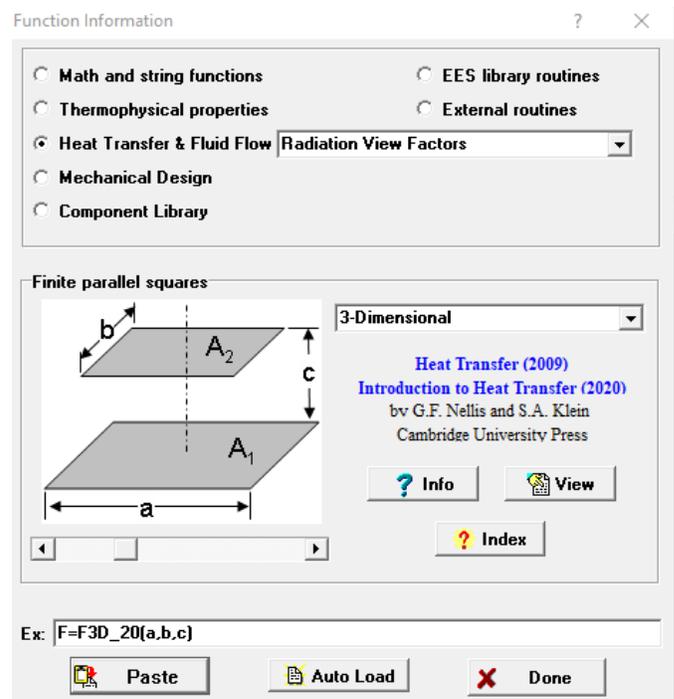
This 40th issue of EESy Solutions provides news and tips for users of the Engineering Equation Solver software. This issue introduces a generally useful radiation view factor function that can determine the view factor between any two arbitrarily oriented planar surfaces. The 3D plotting package has been improved to better visualize these planar surfaces. The properties available for ice have been substantially improved. Finally, two new plot types have been introduced: Symbol Color and Area Plots.

EES has been commercially available for more than two decades. Previous issues of EESy Solutions can be downloaded from www.fchartsoftware.com.

The View Factor Procedure F3D_Poly

The View Factor Library in EES can be accessed by selecting Heat Transfer & Fluid Flow in the Function Information dialog and then selecting Radiation View Factors. This is just one of many libraries that are available with the Heat Transfer Library in EES.

The majority of these view factors are very specific, providing the view factor from one precisely defined surface to another with the surfaces oriented relative to each other in a certain way. For example, the function F3D_20 provides the view factor between two square planes that are oriented parallel to one another and centered on top of one another, as shown.



The Function Information dialog for the view factor function F3D_20.

The View Factor Procedure F3D_Poly (continued)

The view factor procedure F3D_Poly is a much more general procedure that can provide the view factor between any two planes defined as polygons that are arbitrarily oriented relative to one another. The only conditions that must be met are:

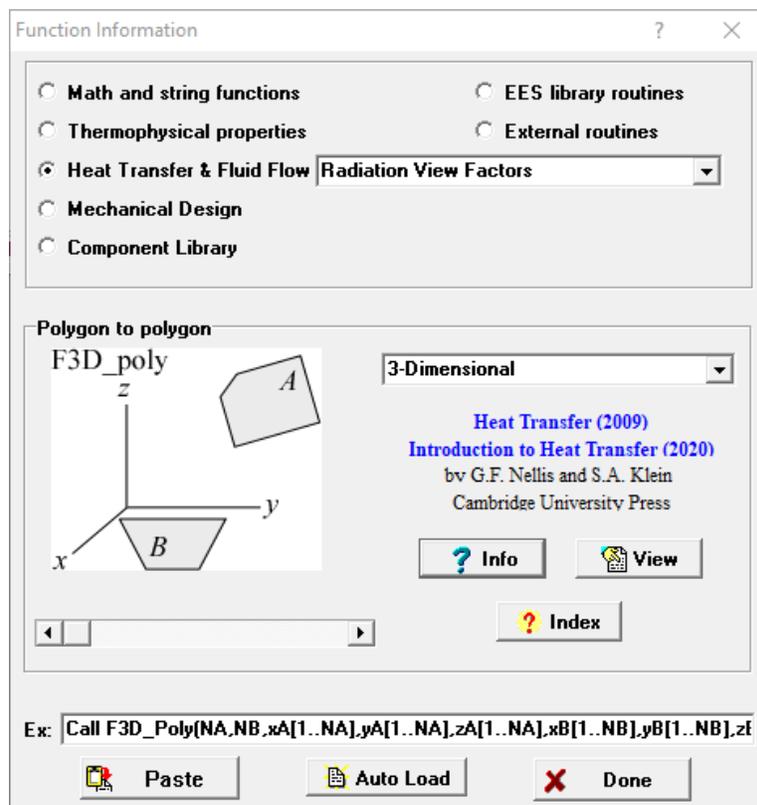
1. Polygons must be simple (i.e., they cannot be self-intersecting), and
2. Polygons are convex

This procedure is based on the solution provided by Narayanaswamy, A., "An analytical expression for radiation view factor between two arbitrarily oriented planar polygons," *Int. J. Heat & Mass Transfer*, Vol. 91 (2015) and adapted by Jacob Kerkhoff, a student at the UW-Madison Solar Energy Lab. It can be accessed from the Function Information Dialog by selecting Radiation View Factors from the Heat Transfer & Fluid Flow Library and then selecting 3-Dimensional; F3D_Poly is the first one that comes up as you scroll. The view factor inputs specify the geometry of the two polygons (A and B) and the outputs provide the view factors (F_{AB} and F_{BA}) and the areas (areaA and areaB).

NA, NB = # vertices for polygons A and B

$x_A[1..NA]$, $y_A[1..NA]$, and $z_A[1..NA]$ = x, y, and z coordinates of the vertices for polygon A

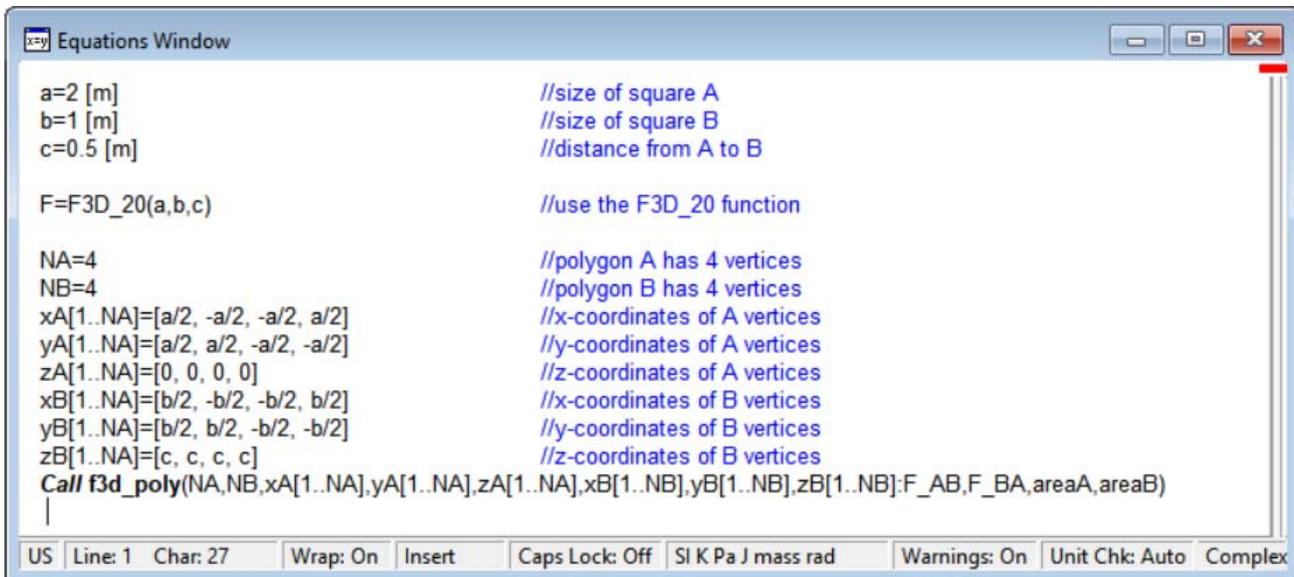
$x_B[1..NB]$, $y_B[1..NB]$, and $z_B[1..NB]$ = x, y, and z coordinates of the vertices for polygon B



The Function Information dialog for the view factor procedure F3D_poly.

The View Factor Procedure F3D_Poly (continued)

The F3D_Poly function can be used to provide many of the view factors that are currently provided by other functions in the radiation view factor library as well as many not available in any other way. For example, F3D_20 provides the view factor for two square planes that are parallel and centered. The code below uses both F3D_20 and F3D_Poly to compute this view factor and shows that they return identical answers.



```

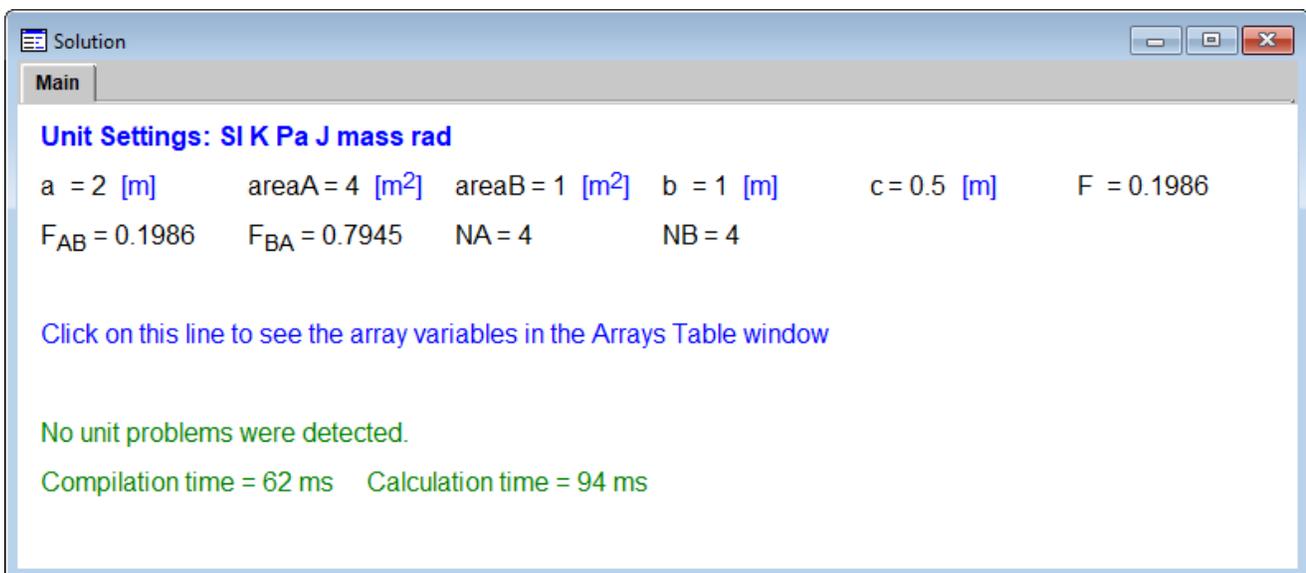
Equations Window
a=2 [m] //size of square A
b=1 [m] //size of square B
c=0.5 [m] //distance from A to B

F=F3D_20(a,b,c) //use the F3D_20 function

NA=4 //polygon A has 4 vertices
NB=4 //polygon B has 4 vertices
xA[1..NA]=[a/2, -a/2, -a/2, a/2] //x-coordinates of A vertices
yA[1..NA]=[a/2, a/2, -a/2, -a/2] //y-coordinates of A vertices
zA[1..NA]=[0, 0, 0, 0] //z-coordinates of A vertices
xB[1..NB]=[b/2, -b/2, -b/2, b/2] //x-coordinates of B vertices
yB[1..NB]=[b/2, b/2, -b/2, -b/2] //y-coordinates of B vertices
zB[1..NB]=[c, c, c, c] //z-coordinates of B vertices
Call f3d_poly(NA,NB,xA[1..NA],yA[1..NA],zA[1..NA],xB[1..NB],yB[1..NB],zB[1..NB]:F_AB,F_BA,areaA,areaB)
  
```

US Line: 1 Char: 27 Wrap: On Insert Caps Lock: Off SI K Pa J mass rad Warnings: On Unit Chk: Auto Complex

Equations Window showing call to F3D_20 and F3D_Poly



```

Solution
Main
Unit Settings: SI K Pa J mass rad
a = 2 [m]    areaA = 4 [m2]    areaB = 1 [m2]    b = 1 [m]    c = 0.5 [m]    F = 0.1986
FAB = 0.1986    FBA = 0.7945    NA = 4    NB = 4

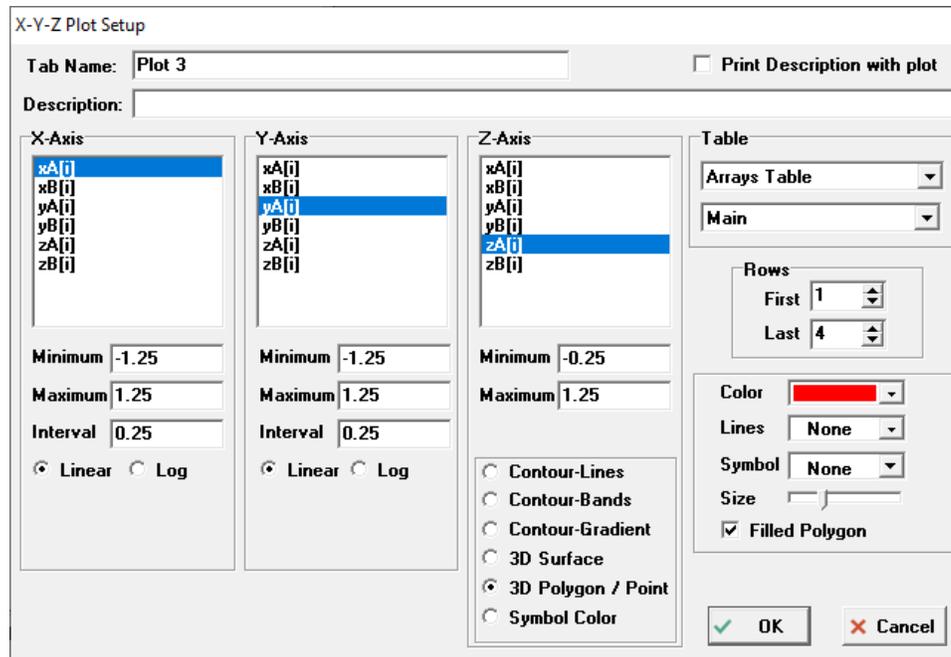
Click on this line to see the array variables in the Arrays Table window

No unit problems were detected.
Compilation time = 62 ms    Calculation time = 94 ms
  
```

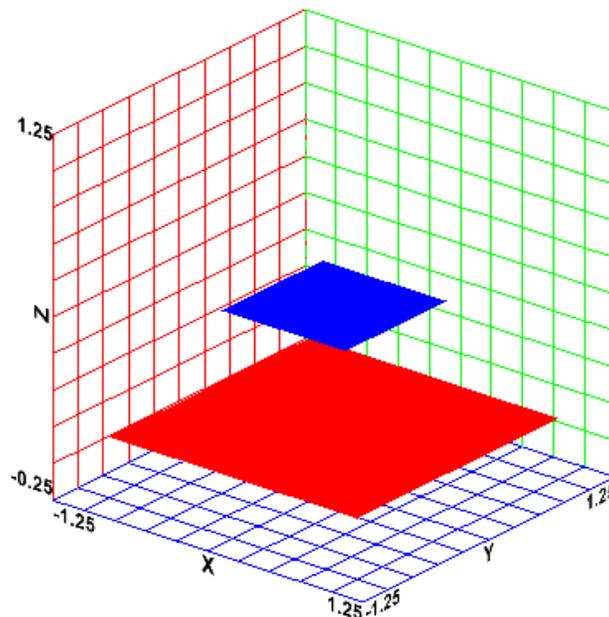
Solutions Window showing both functions provide the same view factor (compare F to F_{AB})

Improvements to 3D Plotting

The types of 3D plots that can be created have been expanded, in part to make it easier to visualize polygons in 3D space. The X-Y-Z plotting dialog now includes the 3D Polygon/Point plot option which generates polygon surfaces. We can plot the two polygons in our previous example by selecting New Plot Window from the Plots menu and then X-Y-Z Plot. Select xA, yA, and zA as the x, y, and z-axis points and then 3D Polygon/Point to plot Polygon A. Select Overlay plot and do the same thing for xB, yB, and zB to place Polygon B onto the same plot.



X-Y-Z Plot Setup Dialog



Polygons A and B using the 3D Polygon plot

Improvements to 3D Plotting (continued)

It's possible to generate these 3D plots using a macro with the Professional license. This capability allows automatic generation of a plot showing the polygons any time that you adjust their geometry. For example, the Equations Window below shows a macro entered after the previous example. The macro will run after the EES code is solved using the \$RunMacroAfter directive. The macro deletes two plots (if they exist) and then recreates them based on the current vertices stored in the arrays.

```

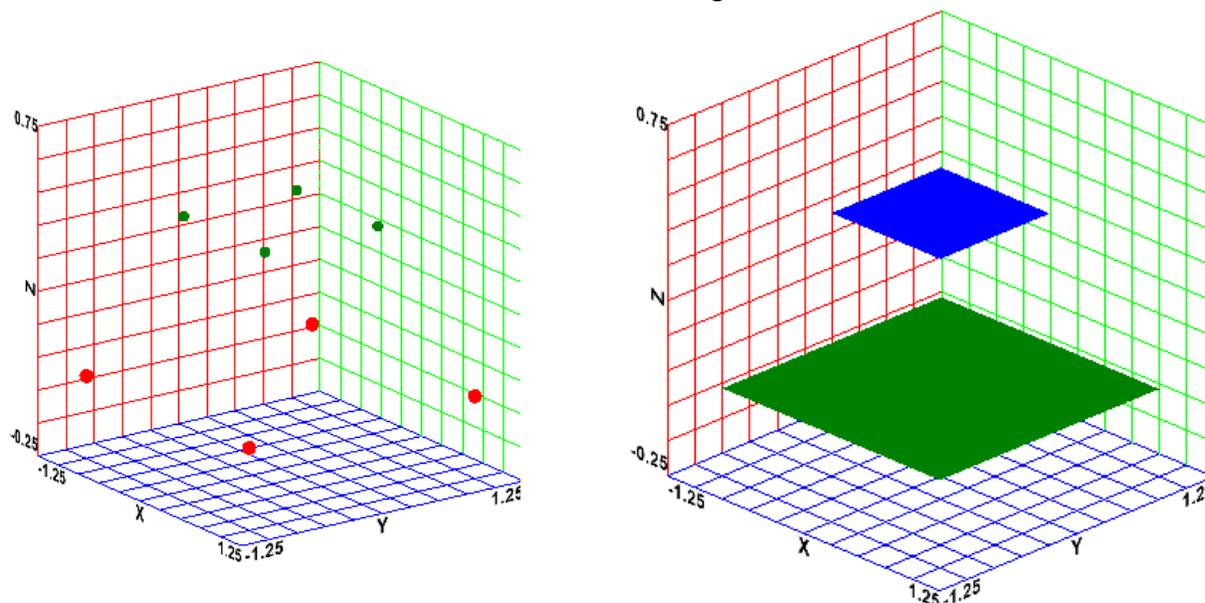
Equations Window
a=2 [m] //size of square A
b=1 [m] //size of square B
c=0.5 [m] //distance from A to B

F=F3D_20(a,b,c) //use the F3D_20 function

NA=4 //polygon A has 4 vertices
NB=4 //polygon B has 4 vertices
xA[1..NA]=[a/2, -a/2, -a/2, a/2] //x-coordinates of A vertices
yA[1..NA]=[a/2, a/2, -a/2, -a/2] //y-coordinates of A vertices
zA[1..NA]=[0, 0, 0, 0] //z-coordinates of A vertices
xB[1..NA]=[b/2, -b/2, -b/2, b/2] //x-coordinates of B vertices
yB[1..NA]=[b/2, b/2, -b/2, -b/2] //y-coordinates of B vertices
zB[1..NA]=[c, c, c, c] //z-coordinates of B vertices
Call f3d_poly(NA,NB,xA[1..NA],yA[1..NA],zA[1..NA],xB[1..NB],yB[1..NB],zB[1..NB],F_AB,F_BA,areaA,areaB)

$RunMacroAfter
DeletePlot 'Points'
New3DPlot Name='Points' Table=ARR X=XA[i] Y=yA[i] Z=zA[i] XMin=-1.25 XMax=1.25 YMin=-1.25 YMax=1.25 ZMin=-0.25 ZMax=0.75 Rows=1..NA Type=Polygon Lines=0 Symbol=1 SymbolSize=10 Color=Red
Overlay3DPlot Name='Points' Table=ARR X=XB[i] Y=yB[i] Z=zB[i] Rows=1..NB Type=Polygon Lines=0 Symbol=1 Color=Green
DeletePlot 'Polygons'
New3DPlot Name='Polygons' Table=ARR X=xA[i] Y=yA[i] Z=zA[i] XMin=-1.25 XMax=1.25 YMin=-1.25 YMax=1.25 ZMin=-0.25 ZMax=0.75 Rows=1..NA Type=Polygon Lines=0 Symbol=0 Color=Green Filled
Overlay3DPlot Name='Polygons' Table=ARR X=XB[i] Y=yB[i] Z=zB[i] Type=Polygon Lines=0 Symbol=0 Color=Blue FILLED
Sendmacro
$HideWindow Solution
  
```

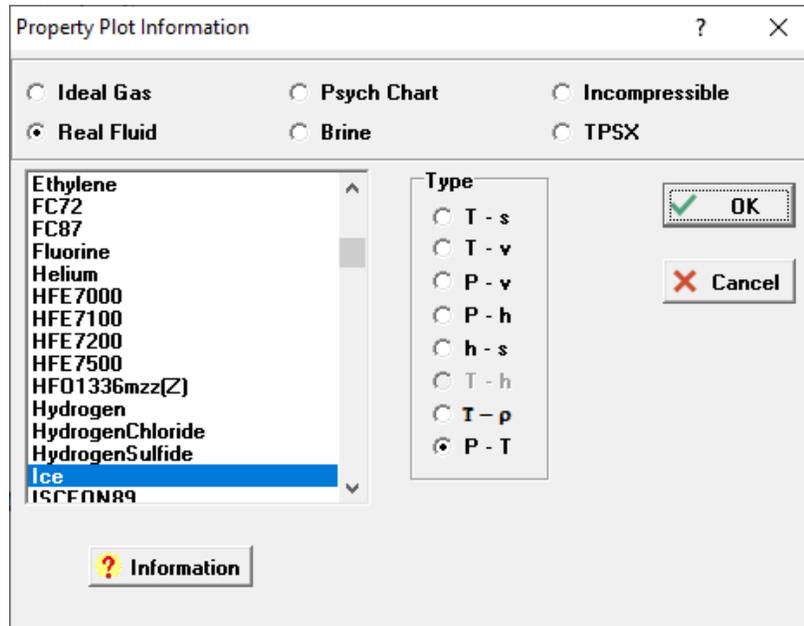
Generate 3D Plots using a Macro



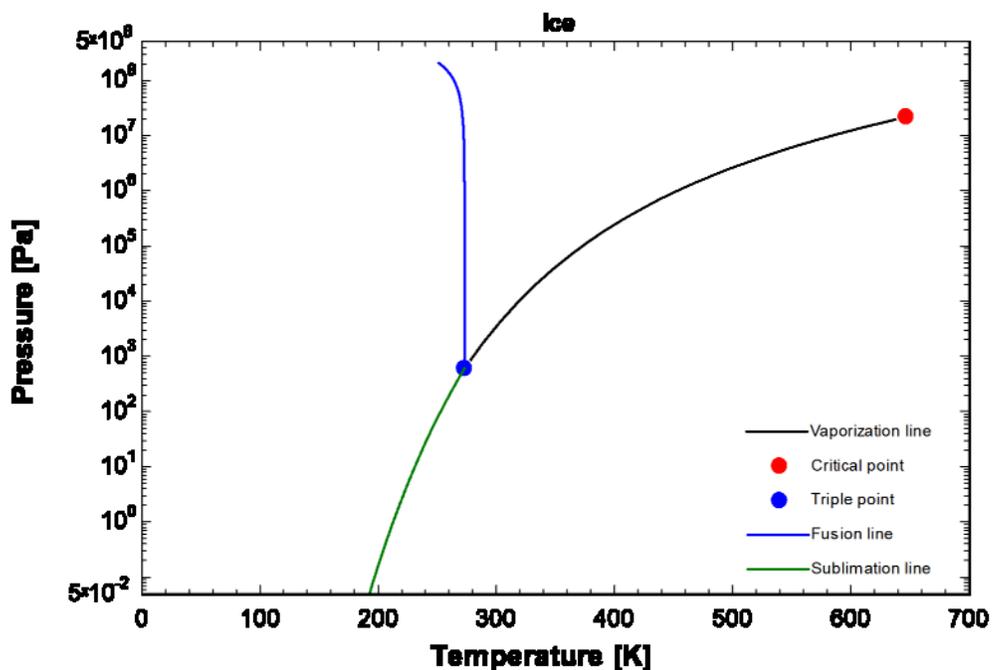
The plots created using the Macro

Properties of Ice

The thermodynamic properties of pure water are implemented in EES using a number of substance identifiers, e.g., Water, Steam, Steam_IAPSW, and Ice. The substance "Ice" is specifically meant to accurately provide the properties of solid water, although it also provides properties in the liquid and vapor regions as well. The functions P_melting, P_sublimation and T_melting have been implemented for substance Ice and the property plot now allows the creation of a pressure-temperature plot that shows the solid, liquid, and gas regions for ice and other substances. The SoundSpeed function has also been implemented for the substance Ice.



Property Plot Information Dialog showing P-T Plot for Ice



P-T Plot for Ice

Symbol Color 3D Plots

A new type of 3D plot is available with a Professional EES license. A Symbol Color plot can be selected in the X-Y-Z Plot Setup dialog. This option generates a typical 2-D (X-Y) type plot but the colors used for the symbols are selected based on the value of a third variable (Z). The color scheme used for this purpose (Red-Blue or full spectrum) can be selected.

The table shows data taken from a small electric motor. The data include torque and efficiency at various values of rotational speed. One method of illustrating all of this information in a single plot uses a Symbol Color plot, as shown below.

	Torque [N-m] {[N-mm]}	Speed [rev/s]	Efficiency [-] [%]
Row 1	0.002584 {2.584}	15.63	0.02154 {2.154}
Row 2	0.002366 {2.366}	21.16	0.03005 {3.005}
Row 3	0.002086 {2.086}	25.64	0.03668 {3.668}
Row 4	0.001837 {1.837}	31.25	0.04593 {4.593}
Row 5	0.001557 {1.557}	38.65	0.05776 {5.776}
Row 6	0.001277 {1.277}	44.84	0.0687 {6.87}
Row 7	0.0009964 {0.9964}	50	0.07971 {7.971}
Row 8	0.0006539 {0.6539}	57.6	0.0904 {9.04}
Row 9	0.0003425 {0.3425}	64.1	0.1054 {10.54}
Row 10	0.0001868 {0.1868}	67.57	0.06059 {6.059}
Row 11	0 {0}	74.63	0 {0}

X-Y-Z Plot Setup

Tab Name: Plot 5 Print Description with plot

Description:

X-Axis: Torque [N-m], Torque [N-mm], Speed, Efficiency [-], Efficiency [%]

Y-Axis: Torque [N-m], Torque [N-mm], Speed, Efficiency [-], Efficiency [%]

Color: Torque [N-m], Torque [N-mm], Speed, Efficiency [-], Efficiency [%]

Table: Lookup Table, data

Rows: First 1, Last 11

Symbol: Red-Blue Spectrum

Show every 1 pts

Line Type: None

Include Legend

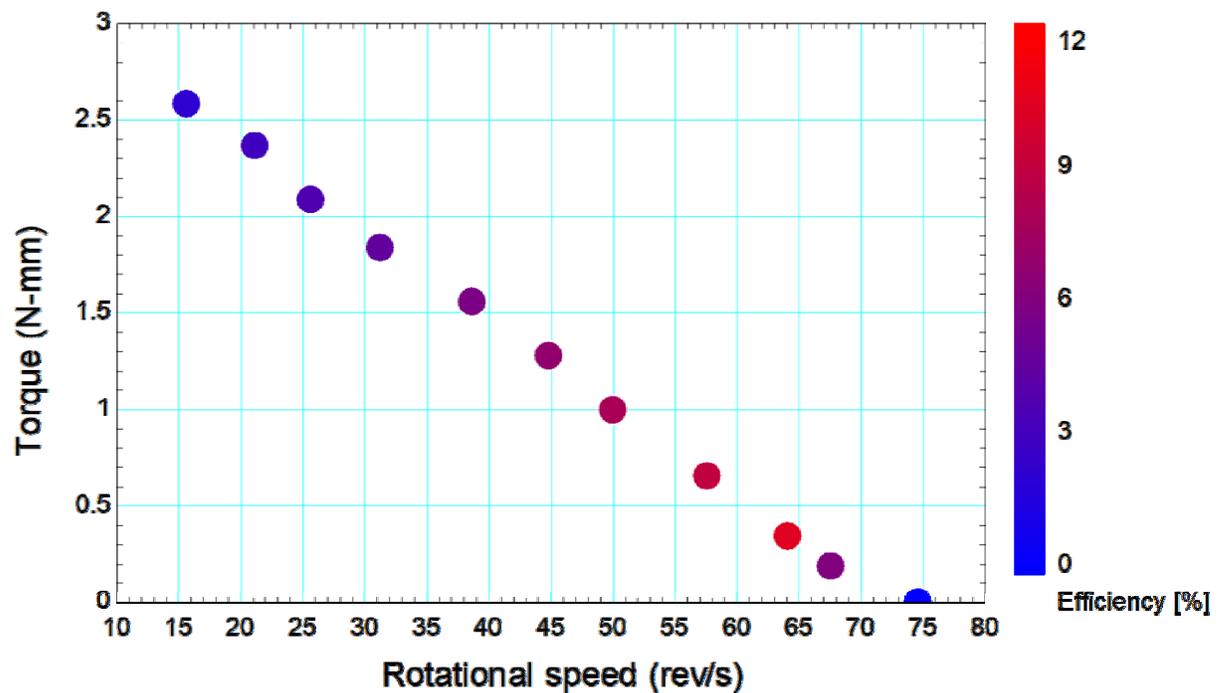
Type: 3-column data 2-D table data

Contour-Lines Contour-Bands Contour-Gradient 3D Surface 3D Polygon / Point Symbol Color

OK Cancel

Data in Lookup Table

X-Y-Z Plot Setup Dialog showing the Symbol Color Plot



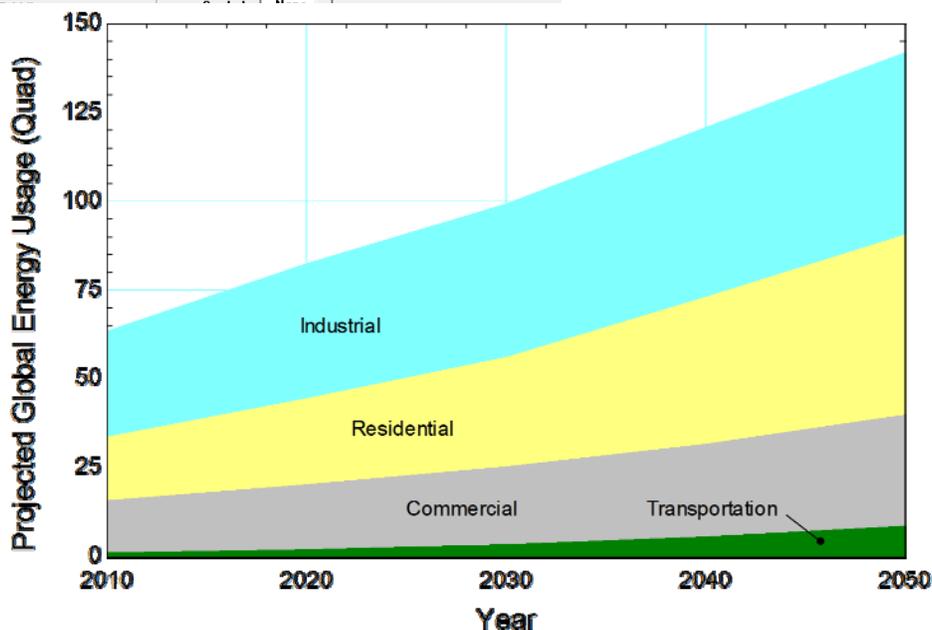
Symbol Color Plot of Data

Area Plots

Area plots can be generated using a Professional EES license. An area plot is a 2-D (X-Y) plot but the area below each plot line is filled with a selected color. For example, the table to the right provides projections for global energy use (in Quadrillion Btu) for various sectors (from the U.S. EIA). A simple line plot provides each of these individually as a function of time. However, an alternate way of displaying these data is to show the total energy use including subsets of the sectors with an area plot. To do this, additional columns are added to the table (using the Alter Values and Equation option) corresponding to Transportation + Commercial (T+C), T+C+R, and T+C+R+I (or total). An Area Plot is generated by selecting New Plot Window from the Plots menu and then selecting X-Y plot. Select the data to be plotted (T, T+C, T+C+R, and T+C+R+I) and then select area plot under the Line drop down menu. Note that the last data series plotted will be placed in front of all other plots so it will be necessary to reorder how the data series are plotted using the Modify Plot Dialog. The result is an area plot showing how each sector's energy usage adds together to provide the total energy usage.

	1	2	3	4	5
Energy projections	Year	Transportation	Commercial	Residential	Industrial
Row 1	2010	1.02	14.7	17.9	29.8
Row 2	2020	1.9	18.3	24.2	38
Row 3	2030	3.33	21.9	30.8	43.2
Row 4	2040	5.54	26.1	41.3	47.8
Row 5	2050	8.54	31.3	50.7	51.3

6	7	8
T+C	T+C+R	T+C+R+I
15.72	33.62	63.42
20.2	44.4	82.4
25.23	56.03	99.23
31.64	72.94	120.7
39.84	90.54	141.8



Other Recent Changes to EES

- The regenerator packings library has been improved.
- Property data are provided for Propyne, R 512, R470B, R470A, and R428.
- Viscosity and thermal conductivity for fluid properties that are obtained using REFPROP.FLD files are provided using a corresponding states approach with propane as the reference fluid.
- Input and output variables in the Diagram Window can now be entered and displayed in the variable's alternate unit system with the Professional license.
- The Finned Circular Tube section of the Compact Heat Exchanger Library has been improved.
- The Find dialog provides an auto-complete option to help find existing variables in the EES program.
- Color and font style used for string constants in the Equations Window can be specified on the Syntax page of the Preferences Dialog.
- The mouse wheel can be used to scroll through the list of variables in the Variable Information Window.
- The expansion and contraction pressure loss coefficients for various heat exchangers are now included in the Minor Losses and Flow Coefficients library.
- The Make Distributable Command now provides a Zip Files option that will zip the executable file and all selected files and libraries into a single zip file for easy distribution.
- A \$RunMacroBefore directive now allows a set of macro commands to be run from the Equations Window prior to initiating the calculations.
- The procedures External_Flow_Finned_Bank1 and External_Flow_Finned_Bank2 provide the average heat transfer coefficient and total pressure drop for flow over an inline and staggered bank of finned tubes, respectively.
- Holding the Alt key down while selecting the Copy menu command for data in a table causes the data to be copied in a transposed manner.
- The effectiveness of a counterflow heat exchanger with cross-flow headers is now available in the Heat Exchanger library.
- The Procedure Flow_Boiling_Hamilton function in the Heat Transfer library implements the Hamilton correlation that can be used for both pure refrigerants and blends.



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Instant Update & Technical Service

EES uses a different model for updating than most other programs. Each time that there is a change in the EES program, either to correct a problem or to add a new feature, the version number is incremented by 0.001 and the latest version of EES is placed on our website. Although the program has become very robust and stable, there have been many new versions of EES released since the last EESy Solutions was distributed.

Access to our website to download the current non-academic version of EES requires a subscription to [Instant Update and Technical Service \(IUTS\)](#). All new non-academic licenses of EES are provided with one year of IUTS. The service can be renewed from our webstore for a cost of 20% of the initial cost provided that it is renewed within one year after expiration.

Access to the current Academic version requires an annual subscription to [Academic Update Service](#).