FC F-Chart Software

EESy Solutions
Engineering Equation Solver Newsletter

Inside this issue:

Welcome

This is the 39th issue of EESy Solutions, a newsletter that provides news, tips, and other updates for users of the Engineering Equation Solver software. This issue introduces the new TPSX library that contains thermophysical data for a large number of incompressible substances. Also, procedures are discussed that allow you to use the linear regression and curve fitting capability of EES from within the Equations Window .

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

Academic Update Service for 2020

Up to and including the 2019-2020 Academic version, the EES program expired on September 1 of the following year. As a result, it had been necessary for academic departments to replace their existing EES programs each year with a newer version that was made available at no cost.

This policy changed in June of this year. The Academic version of EES that was released in June, 2020 will not expire and it will no longer be necessary to replace the program. However, free access to our website to download the EES setup program ended on September 1, 2020. Access to the setup program for the current Academic version and technical support are only available with an annual subscription to the Academic Update Service (AUS). The cost of this optional service is $500 per year for the Academic Commercial version and $1000 per year for the Academic Professional version. Academic Update Service will allow departments to access the most recent version of EES and take advantage of program enhancements that were introduced after September 1, 2020. Academic Update Service may be ordered at any time. Departments that do not have a subscription to Academic Update Service can continue to use the Academic version of EES released in June 2020.

To summarize:
- The Academic Version of EES provided in June 2020 will not expire.
- It is possible to upgrade to the most recent Academic version of EES with an annual subscription to Academic Update Service (AUS).
- Technical support requires a subscription to Academic Update Service (AUS).

The TPSX Library

The Thermal Protection Materials Branch at NASA has developed and maintains a web-based database for a large number of incompressible materials. These data are unrestricted and non-proprietary (as described in https://www.nasa.gov/centers/ames/thermal-protection-materials/database.html). The data have been extracted and are now available in the Professional Version of EES for versions 10.836 or newer.

To access the TPSX database it must first be loaded using the $Load directive placed at the top of your EES file:

$Load TPSX

The database is accessed by selecting the TPSX radio button from the Thermophysical properties Function Information dialog. The materials are organized by category according to the middle dropdown menu. For example, to see the Polyamides included in the database select Polyamides. Some of these material properties are pressure-dependent and therefore in some cases the pressure is included in the name (e.g., Nomex_FRSI_1kPa_NJPM are the properties of Nomex at 1 kPa). The properties available for the selected material are listed in the left-hand box. A facsimile function call is provided in the Ex. Box and it can be edited and pasted into the Equations Window by clicking the Paste button.
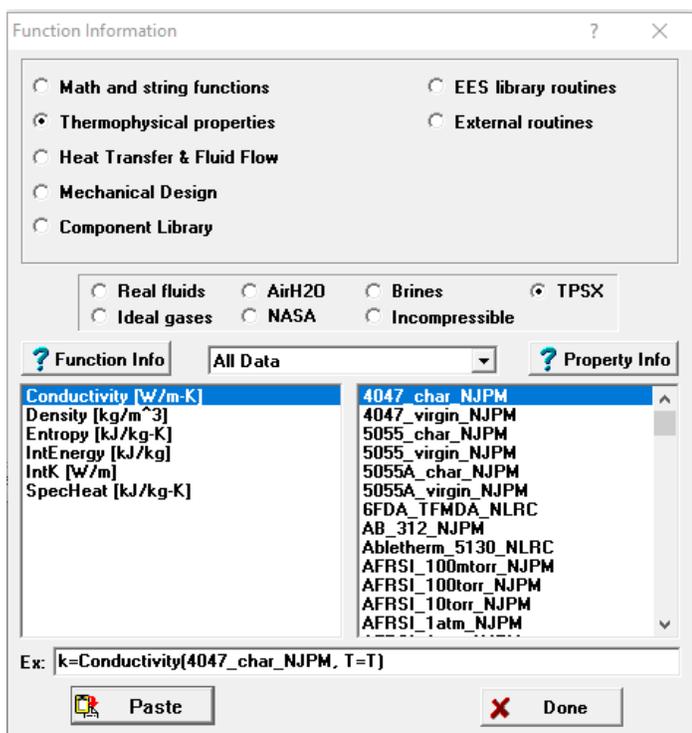
TPSX with All Data included　　　　　*TPSX showing only Polyamides*
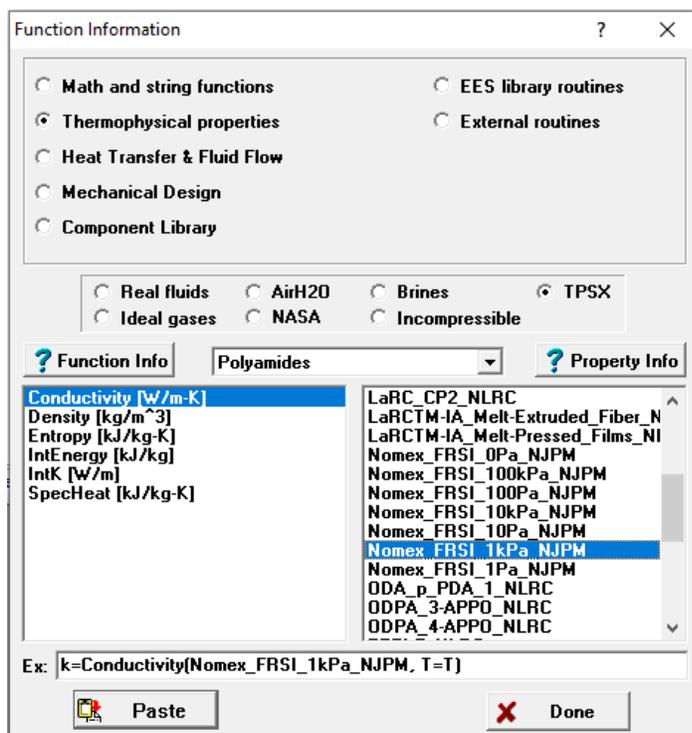
The TPSX Library (continued)

Information about the selected substance can be obtained by selecting the Property Info button.

Property Information for Nomex_FRSI_1kPa_NJPM			? ✕
Composition: aromatic polyamide felt Manufacturer: DuPont NASA JSC PathFinder Materials, https://tpsx.arc.nasa.gov|			
Property	**Function Name**	**Lower Limit [C]**	**Upper Limit [C]**
Density	Density	Room	Temperature
Specific Heat	SpecificHeat or Cp or Cv	-156.5	538
Emissivity	Emissivity	Room	Temperature
Thermal Conductivity	Conductivity	-156.5	1094
Integrated Thermal Conductivity	IntK	-156.5	1094
Specific Internal Energy	IntEnergy	-156.5	538
Specific Entropy	Entropy	-156.5	538
? Help	📈 Plot	✕ Done	

Note that the first line includes some useful information about the material from the website. The temperature range of each of the properties are also included. Finally, by selecting the Plot button it is possible to obtain a property plot. For example, if you select Specific Heat and then Plot, the property plot shown below will be generated showing the specific heat capacity of Nomex at 1 kPa as a function of temperature. The actual data can be shown by modifying the plot to place a symbol at each point.
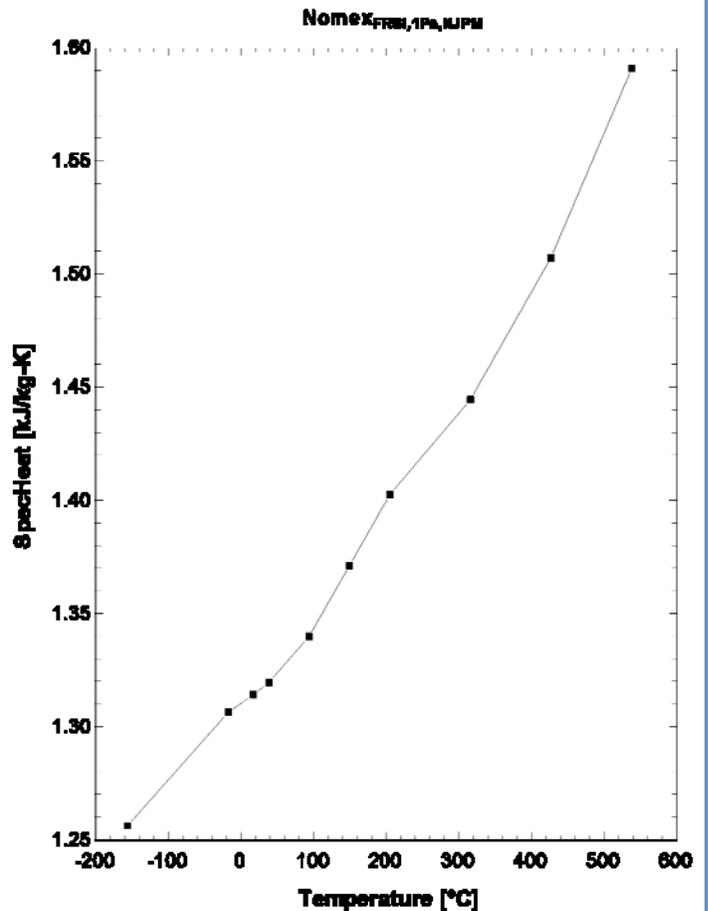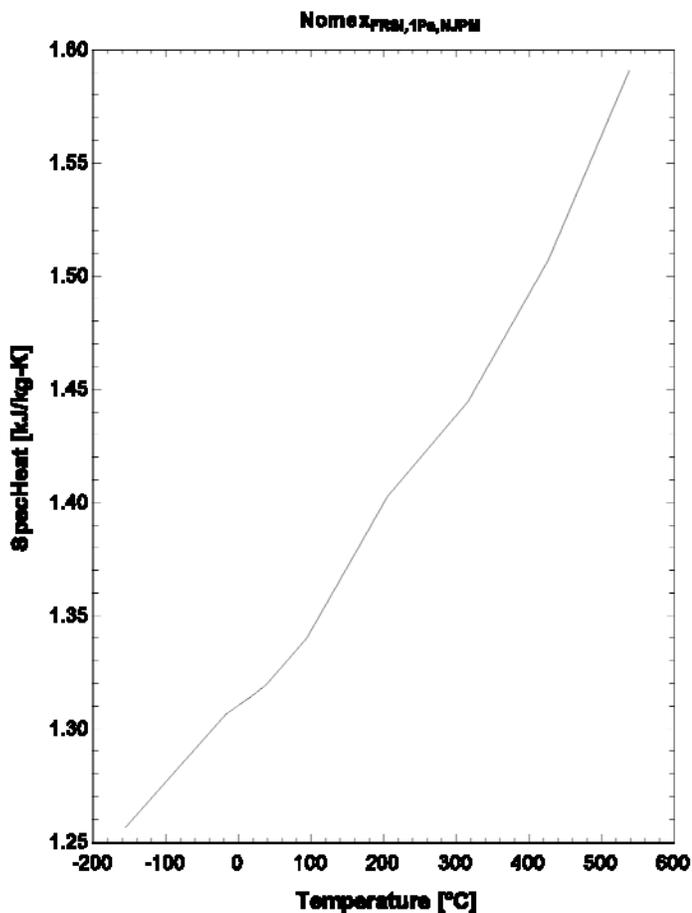
The LinearRegression Procedure

The Linear Regression command in the Tables menu in EES data contained in an Arrays Table or a Lookup Table to be fit to a linear function involving up to 12 independent variables. For example, consider the pump curve shown. The Lookup Table 'PumpCurve' includes data read from the plot at 4 different flow rates for each of 3 different impeller diameters. We might want to develop a curve fit to these data that would allow the prediction of the pressure rise at any arbitrary flow rate and impeller diameter.

	DP [ftH2O]	$\dot{V}$ [gpm]	D [inch]
Row 1	47	0	7
Row 2	46	150	7
Row 3	42	300	7
Row 4	30	450	7
Row 5	72	0	8.5
Row 6	70	200	8.5
Row 7	63	400	8.5
Row 8	42	600	8.5
Row 9	91	0	9.5
Row 10	90	200	9.5
Row 11	84	400	9.5
Row 12	54	750	9.5
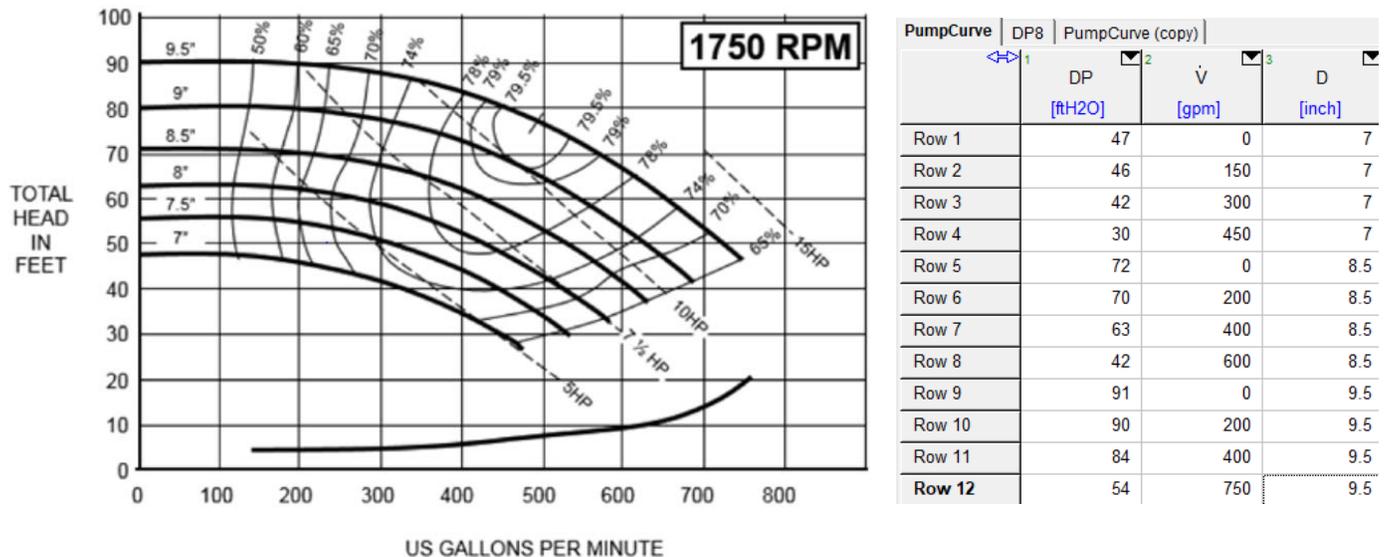
We can determine the coefficients for the curve fit equation by selecting Linear Regression from the Tables menu and then selecting the dependent and independent variables as well as the form of the equation. A second order fit with cross terms is used here. Select Fit to obtain the best-fit coefficients.

$$DP = 5.17250832E1 - 4.87910994E\text{-}2 \cdot V\_dot - 9.70399300E\text{-}5 \cdot V\_dot^2 - 1.34720185E1 \cdot D + 1.85078335 \cdot D^2 + 7.46701856E\text{-}3 \cdot V\_dot \cdot D$$

The LinearRegression Procedure (continued)

The LinearRegression Procedure introduced in EES version 10.887 allows the curve fit to be accomplished programmatically using up to 100 independent variables. Using the procedure allows you to fit a function to a table of data within your EES code and then use the fit in subsequent calculations. If the data change, then the fit will automatically change as well.

The calling protocol for the LinearRegression Procedure is shown below:

Call LinearRegression(T$, Row1, RowN, DepVar$, NInd, IndVars$[1..Nind], Exclude0: &
    A[0..Nind], rms, bias, R2, StdErr[0..Nind])

The inputs are:
   T$ = Name of the Lookup table containing the data or 'Arrays' for the Arrays table.
   Row1 and RowN = first and last row of data in the table to use for curve fit, respectively
   DepVar$ = name of the column in the table containing the dependent variable
   NInd = number of independent variables. (NInd must be between 1 and 100)
   IndVars$[1..Nind] = array of strings containing the names of the columns containing the NInd independent variables
   Exclude0 = either false# (0) or true$ (1) depending on whether you want to include a constant in the curve fit

The outputs are:
   A[0..Nind] = constants in the curve fit (included in the order defined by IndVars$[1..Nind]
   rms, bias, etc. are all optional values that describe the statistics of the curve fit.

In order to use the curve fit using the LinearRegression Procedure, it is necessary to have a column in the table corresponding to each of the independent variables. Therefore we need to add columns for V_dot^2, D^2 and V_dot*D for the regression equation used here.

$$DP = a_0 + a_1 V\_dot + a_2 V\_dot^2 + a_3 D + a_4 D^2 + a_5 V\_dot\ D$$

This can be done using the Alter Values command with the Enter Equation option.

	DP [ftH2O]	$\dot{V}$ [gpm]	D [inch]	$\dot{V}2$ [gpm2]	D2 [inch2]	V_{dotD} [gpm-inch]
Row 1	47	0	7	0	49	0
Row 2	46	150	7	22500	49	1050
Row 3	42	300	7	90000	49	2100
Row 4	30	450	7	202500	49	3150
Row 5	72	0	8.5	0	72.25	0
Row 6	70	200	8.5	40000	72.25	1700
Row 7	63	400	8.5	160000	72.25	3400
Row 8	42	600	8.5	360000	72.25	5100
Row 9	91	0	9.5	0	90.25	0
Row 10	90	200	9.5	40000	90.25	1900
Row 11	84	400	9.5	160000	90.25	3800
Row 12	54	750	9.5	562500	90.25	7125

The LinearRegression Procedure (continued)

Once the independent variables have been set up, use the code below to generate the curve fit.

```
T$='PumpCurve'
N=nlookuprows(T$)                                       "number of rows in the table"
NInd=5                                                  "number of independent variables (columns)"
IndVar$[1..NInd]=['T_cond','T_evap','T2_cond','T2_evap','T2_condevap']  "names of the columns "
Exclude0=false#                                         "determine constant A[0]"
Call linearregression(T$,1,N,'DP',NInd,IndVar$[1..NInd],Exclude0: A[0..NInd],rms1,bias1)
```

$$DP = 5.17250832E1 - 4.87910994E\text{-}2 \cdot V\_dot - 9.70399300E\text{-}5 \cdot V\_dot^2$$
$$- 1.34720185E1 \cdot D + 1.85078335 \cdot D^2 + 7.46701856E\text{-}3 \cdot V\_dot \cdot D$$

Solving leads to the coefficients contained in the Arrays Table, which are identical to those identified manually using the Linear Regression dialog. The curve fit can be used within the EES code.

Main	A_i	IndVar$_i$
Sort		
[0]	51.73	
[1]	-0.04879	V_dot
[2]	-13.47	D
[3]	-0.00009704	V2_dot
[4]	1.851	D2
[5]	0.007467	V_dotD

```
$CheckUnits Off
DP=A[0]+A[1]*V_dot+A[2]*D+A[3]*V_dot^2+A[4]*D^2+A[5]*V_dot*D
$CheckUnits On
D=8 [inch]
V_dot=50 [gpm]
```

The CurveFit1D and CurveFit1DT Procedures

Just as the LinearRegression Procedure allows programmatic access to the Linear Regression capabilities in EES, the CurveFit1D and CurveFit1DT Procedures allow you to take advantage of the curve fitting features that are otherwise accessed by selecting Curve Fit from the Plots menu.

The Lookup Table 'DP8' contains pressure rise/flow rate data for the 8 inch impeller pump curve used in the previous example. We can obtain a curve fit to these data by making a plot and then selecting Curve Fit to access the Curve Fit Plotted Data dialog.
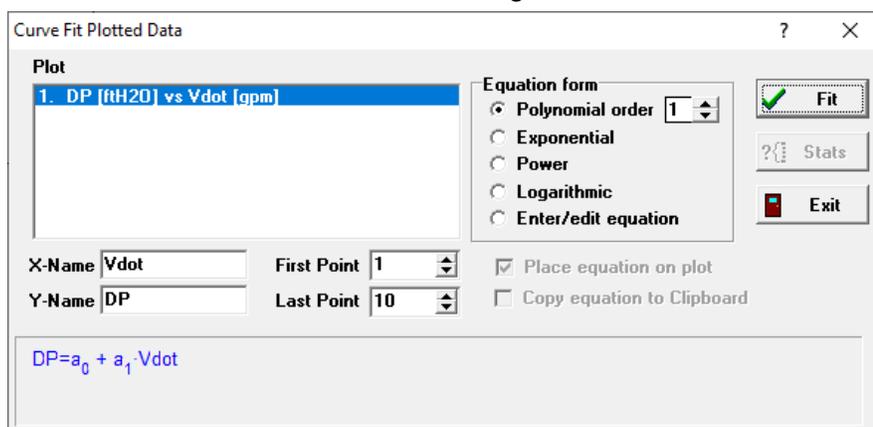
DP8 PumpCurve	$\dot{V}$ [gpm]	DP [ftH2O]
Row 1	0	63
Row 2	100	63
Row 3	200	62
Row 4	250	60.3
Row 5	300	58.5
Row 6	350	56
Row 7	400	53
Row 8	450	47
Row 9	500	43
Row 10	550	36.5

Curve Fit Plotted Data dialog:

Plot: 1. DP [ftH2O] vs Vdot [gpm]

Equation form: Polynomial order 1, Exponential, Power, Logarithmic, Enter/edit equation

Fit, Stats, Exit

X-Name: Vdot   First Point: 1
Y-Name: DP   Last Point: 10

☑ Place equation on plot
☐ Copy equation to Clipboard

$DP = a_0 + a_1 \cdot Vdot$

The CurveFit1D and CurveFit1DT Procedures (continued)

The CurveFit1D Procedure operates on data in Array Tables while the CurveFit1DT Procedure introduced in version 10.861 uses data in a Lookup Table. Here the data are in a Lookup Table so we'll use the latter procedure. The calling protocol is:

Call CurveFit1DT(FType$, T$, XCol$, YCol$, Row1, RowN: A[1..M], rms, bias, R|2, StdErr[1..M])

The inputs are:
   FType$ = A string that indicates the type of fit - the choices are listed below.

Description	FitType$ String	Form of curve fit
Linear fit	'Linear'	$y = a_0 + a_1 x$
1st order polynomial	'Polynomial 1' or 'Poly1'	$y = a_0 + a_1 x$
2nd order polynomial	'Polynomial 2' or 'Poly2'	$y = a_0 + a_1 x + a_2 x^2$
3rd order polynomial	'Polynomial 3' or 'Poly3'	$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$
4th order polynomial	'Polynomial 4' or 'Poly4'	$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$
5th order polynomial	'Polynomial 5' or 'Poly5'	$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5$
6th order polynomial	'Polynomial 6' or 'Poly6'	$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 + a_6 x^6$
Exponential fit	'Exponential' or 'Exp'	$y = a_0 \exp(a_1 x)$
Power	'Power'	$y = a_0 x^{a_1}$
Logarithmic	'Logarithmic' or 'Log'	$y = a_0 + a_1 \ln(x)$

   T$ = Name of table containing the data
   XCol$ and YCol$ = the names of the columns containing the x- and y- data, respectively
   Row1 and RowN = first and last row of data in the table to use for curve fit, respectively

The outputs are:
   A[0..M] = constants in the curve fit
   rms, bias, etc. are all optional values that describe the statistics of the curve fit.

The following code calls the CurveFit1DT Procedure for the data in the Lookup Table 'DP8' in order to obtain the coefficients for a 3rd order polynomial fit.

```
FType$='Polynomial 3'                    "type of fit"
T$='DP8'                                 "name of table"
XCol$='V_dot'                            "name of x column"
YCol$='DP'                               "name of y column"
N=nlookuprows(T$)                        "number of rows in the table"

Call curvefit1dt(FType$, T$, XCol$, YCol$, 1, N: A[1..4])
```

The curve fit parameters can be used directly in the Equations Window:

```
DP_fit=A[1]+A[2]*V_dot+A[3]*V_dot^2+A[4]*V_dot^3
```

The CurveFit1D and CurveFit1DT Procedures (continued)

The result is the curve fit shown here.
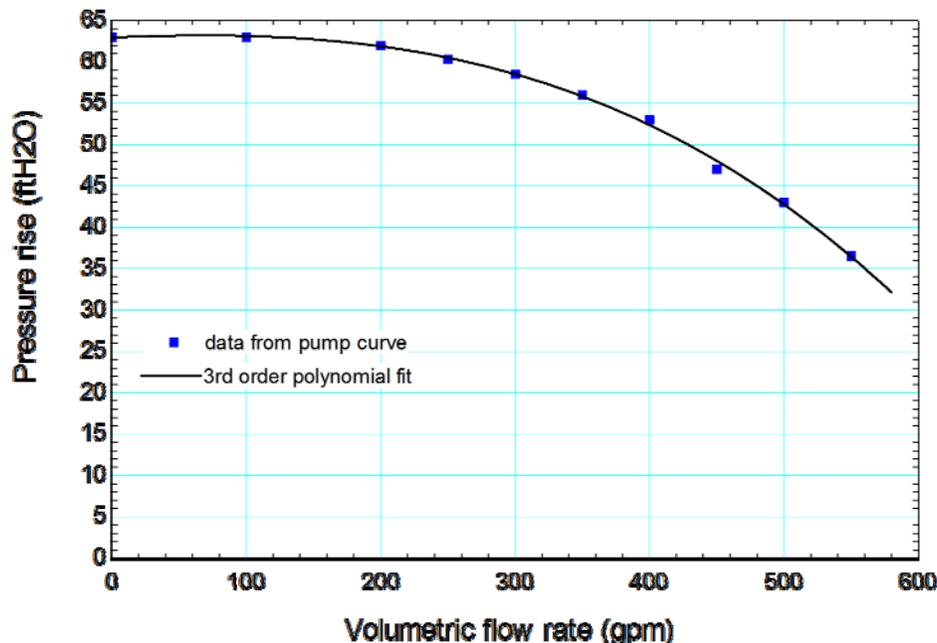
Useful Tip for Finding Array Variables in the Variable Info Window

It can be cumbersome to locate the row in the Variable Information dialog that corresponds to a particular array element when the EES program contains many large arrays. For example, suppose you have a program that uses arrays x[], y[], and z[], each having a dimension of 100. You now want to change the guess value for z[1]. To do so in the Variable Information dialog, you need to scroll to the first element in the z array, which is row 201. A simple way to do this is to collapse the arrays by unchecking the Show array variables check box so that the arrays are represented as x[], y[], and z[]. Select z[] by clicking on it. Now check the Show array variables check box to expand the arrays. The list of variables show the first element in the z array.
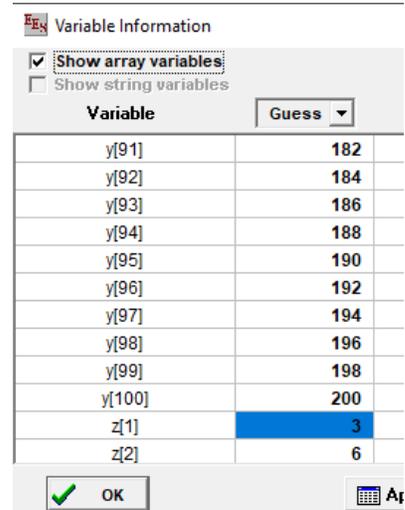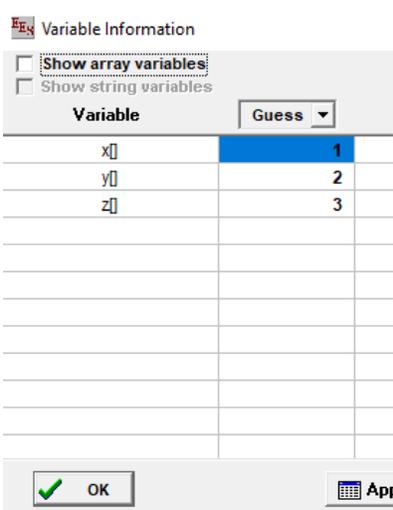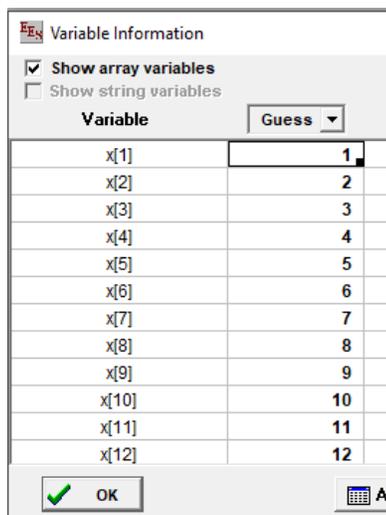
Other Recent Changes to EES

- Macro files saved within a .ees file can be used in a Distributable program
- The Min/Max, Uncertainty and New Parametric Table dialogs have been modified in order to make them easier to use for situations where many variables are in arrays. Arrays can be collapsed and expanded in the variables lists to make it easier to select.
- The default lower and upper temperatures used in the T-s, T-v, T-h, and T-rho property plots for real fluids can be adjusted using slider controls.
- The Mechanical Design library has been augmented with function for Gear Design and Endurance limits.
- The Modify Plot dialog allows multiple data series to be selected using the Shift key.
- When multiple data series are selected in the Modify Plot dialog and the plot is configured for time series display, then an autosequence button is provided that automatically assigns these series to sequential frames.
- The Property Plot command now provides the option to plot properties from the Incompressible and TPSX databases.
- The $Load directive now must be used to access the Incompressible, TPSX, NASA, Component and Mechanical Design libraries.
- The Professional version allows a plot to be displayed in the Diagram Window. An example of this capability can be examined by selecting the Display a 'live' plot in the Diagram Window menu item in the Examples menu.
- The Chen flow boiling correlation is available in the Heat Transfer Library.
- The order of the tabs appearing in the main or child Diagram Window can be changed by dragging the tab.
- The $DefaultDirectory directive sets the default directory that is used when opening or saving an .ees file.
- The LinearRegression, CurveFit1D, and CurveFit1DT procedures have been added.
- Clicking the Show Array Variables control in the Variable Information dialog retains the position of the selected variable or array.

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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.

Any user who has a current subscription to our Instant Update Service can download the latest version. All new non-academic licenses of EES are provided with one year of Instant Update Service. The fee to continue Instant Update Service after the first year is 20% of the current cost of the program per year if renewed within 12 months after expiration. Contact F-Chart Software if you wish to re-subscribe to Instant Update Service (IUTS).