

# EESy Solutions

## Engineering Equation Solver Newsletter

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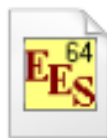
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### Welcome

This is the 29<sup>th</sup> issue of EESy Solutions, a newsletter that provides news, tips, and other updates for users of the Engineering Equation Solver software. This issue provides information on the new 64-bit EES application. New capabilities for the Uncertainty Analysis and other new directives are also highlighted.

EES has been commercially available for more than two decades. If you have missed any of the previous issues of EESy Solutions, they can be downloaded from [fchart.com](http://fchart.com).

### The 64-bit EES Application



The Commercial and Professional versions of EES that have been available for many years are 32-bit Windows applications that are capable of operating on either 32-bit or 64-bit Windows operating systems, such as Windows XP, Vista, 7, 8, and 10. However, a true 64-bit Professional version of EES is now available. The 64-bit application is a different program that operates in exactly the same manner as the 32-bit version. The advantages of the 64-bit version are that it can do calculations significantly faster than the 32-bit version and it allows a maximum of 24,000 variables, compared to 12,000 variables in the 32-bit Professional version. If either of these capabilities is of interest, read on. Otherwise skip to a review of Uncertainty Analyses on page 4.

The 64-bit Professional version of EES will only run on a 64-bit Windows operating systems. All computers are now shipped with 64-bit operating systems, but some older computers may still have a 32-bit operating system installed. The 64-bit version of EES cannot be used on these older computers.

### **The 64-bit License File**

A separate 64-bit license (EES.DFT64) file is required to start the 64-bit application. There is a one-time cost to purchase the 64-bit license file, which is approximately 20% of the current EES license cost. The additional cost to purchase a single-user 64-bit license file is \$240. This license file can be purchased from our [web store](#). Note that a Professional license with a current subscription to Instant Update and Technical Support (IUTS) service is required in order to obtain a 64-bit license file.



### **64-bit Floating-Point Numbers**

Calculation speeds for the 64-bit application are about 2 times faster than the 32-bit applications. This difference can offer a significant advantage for computationally-intensive problems. The major reason that the 64-bit bit version calculates faster is that all floating point numbers are represented with double-precision numbers requiring 64 bits of computer memory. The 32-bit EES applications represent all floating point numbers with double-extended precision requiring 80 bits of memory. Consequently, the 32-bit (Commercial and Professional) applications actually provide greater precision with less round-off error and they also allow larger numerical values than the 64-bit application (1.0E4932 vs 1.0E308). However, these advantages cause the 32-bit version to have slower calculation speed. This difference in floating point number representation also introduces some complications regarding the 32 bit vs the 64 bit file types.



### **64-bit EES File Types**

1. EES stores all information associated with a file in an .EES file. This information includes all of the floating point numbers used for variable information, Parametric and Lookup tables, and plots. In the 32-bit version, the numerical values are stored with 80 bits (10 bytes) of memory. However, in the 64-bit application, these numerical values are stored with 64 bits (8 bytes) of memory. The net result is that different formats are required for the 32 and 64-bit applications for any EES file that contains floating point numbers in binary format. The 64-bit format is identified by appending 64 to the file name extension. Thus, the 64-bit application reads and writes .EES64 bit files, identified with a yellow icon containing 64, as shown above. It reads and saves Lookup tables in .LKT64 files and library files in .LIB64 files. Note that it is the internal structure of the file and not the file name extension that controls whether or not the file contains 64-bit data. Changing the file name extension of an .EES file to be .EES64 does not change the internal information and it will not convert it to be a 64-bit file.
2. The 64-bit application has been designed to read and write 32-bit .EES, .LIB, and .LKT files. As a result, the 64-bit application can read any old or new EES, Library or Lookup table file, written by either the 32-bit or 64-bit applications. However, when reading a 32-bit file, the 64-bit application must convert the numerical format of each floating point number. This process is slow and it may require significant time to read and convert a large 32-bit file. Of course, once opened, the file can be saved in the 64-bit format, which is read quickly by the 64-bit application when it is next opened.



### 64-bit EES File Types (continued)

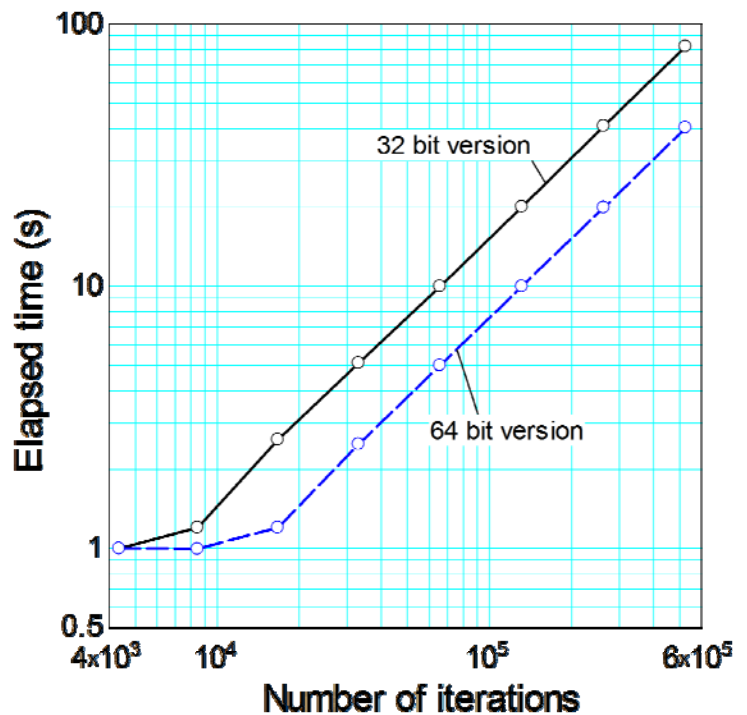
3. EES is capable of using compiled external files in different formats identified by .FDL, .DLF, .DLP, and .DLL file name extensions. Many of these files appear in the Heat Transfer and other libraries in the ..\USERLIB folder. The 64-bit version cannot read compiled external files generated by a 32-bit compiler. It is necessary to recompile these files with a 64-bit compiler. To distinguish these library files, 64 is appended to the compiled external 64-bit files, i.e., .FDL64, .DLF64, .DLP64, and .DLL64. In addition, the library folder has also been renamed to be ..\USERLIB64 to reduce confusion between the 32-bit and 64-bit library files. All of the library files normally included with EES have been converted. Users only need to be concerned with converting library files that they have created.

### Example of Computational Speed Improvement

The advantage of the 64 bit version is most pronounced for problems in which the majority of the time is spent doing calculations (as opposed to compiling, updating the screen, etc.). For example, large programs involving many iterations, optimization problems, parametric studies, and integration type problems all benefit from the use of the 64 bit version of EES.

A simple example of a computationally intensive problem in EES is the use of the genetic optimization algorithm which mimics natural selection by “breeding” many generations of individuals. The figure shows the actual computation time (on an Intel Xeon 3.2 GHz PC) as a function of the number of iterations used in the genetic optimization example Genetic\_test1.ees (or Genetic\_test1.ees64). This example can be selected from the Examples menu by choosing the file ‘Test of the Genetic Optimization algorithm’ in the Minimize or Maximize folder.

The figure shows the elapsed computational time as a function of the number of iterations (varied by changing the number of generations used in the optimization) for the 32 bit and 64 bit versions of EES. Notice that there is little improvement associated with the 64 bit version until the number of iterations reaches approximately 20,000. For larger numbers of computations the 64 bit version is approximately 2x faster in terms of elapsed time than the 32 bit version.



## Uncertainty Analyses

One of the most useful capabilities in EES is its ability to carry out an uncertainty analysis. In an uncertainty analysis, the uncertainty in one or more calculated variables is determined as a function of the uncertainties of the variables upon which it depends. Uncertainty analysis is often used for experiments in which a desired quantity (e.g., heat flow rate) is not directly measured but rather determined from measurements of related quantities, (e.g., temperatures and mass flow rates). Each of the measurements has an associated uncertainty which propagates to affect the uncertainty of the desired quantity. However, uncertainty analysis is not limited to experimental investigations. It can also be very useful in determining the sensitivity of a calculated quantity (e.g., life-cycle cost) to the variables on which it depends, (e.g., economic analysis period, inflation rate, discount rate, etc.)

Uncertainty analysis has been available in EES starting in version 4.616 in 1997. However, the capabilities of the uncertainty analysis have been significantly improved over the last two decades. Originally, EES could determine the uncertainty of one calculated quantity as a function of up to 10 other variables. The current Professional version can simultaneously determine the uncertainty of up to 50 calculated quantities as a function of up to 200 variables. A simple uncertainty analysis calculation is shown next to illustrate some of these capabilities.

### Example: Heat Transfer from a Wire

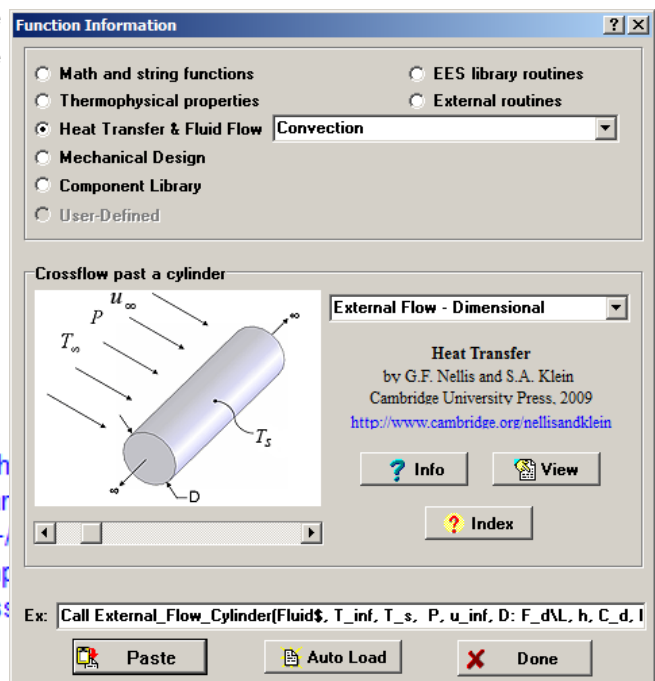
The heat transfer coefficient and rate of heat transfer per length from a heated wire to a cross-flow of air are estimated by measuring the air pressure ( $P$ ), air temperature ( $T_{\infty}$ ), air velocity ( $u_{\infty}$ ) and the wire surface temperature ( $T_s$ ) and diameter ( $D$ ). A very simple EES program that makes use of the Heat Transfer library External\_Flow\_Cylinder convection function is employed to calculate the heat transfer coefficient ( $h$ ) between the air and the wire. Once  $h$  is known, the heat transfer rate per length ( $Q_{\text{dot}}/L$ ) can be calculated. This example can be opened from the Examples menu by selecting the Uncertainty Calculations menu item and then clicking on the 'Uncertainty in heat transfer calculation' file.

\$UnitSystem SI Mass J C kPa Radian  
\$TabStops 2 in

D=5 [mm]\*Convert(mm,m)  
u\_infinity=20 [m/s]  
T\_infinity=27 [°C]  
T\_s=300 [°C]  
P=101.3 [kPa]  
Fluid\$='Air'

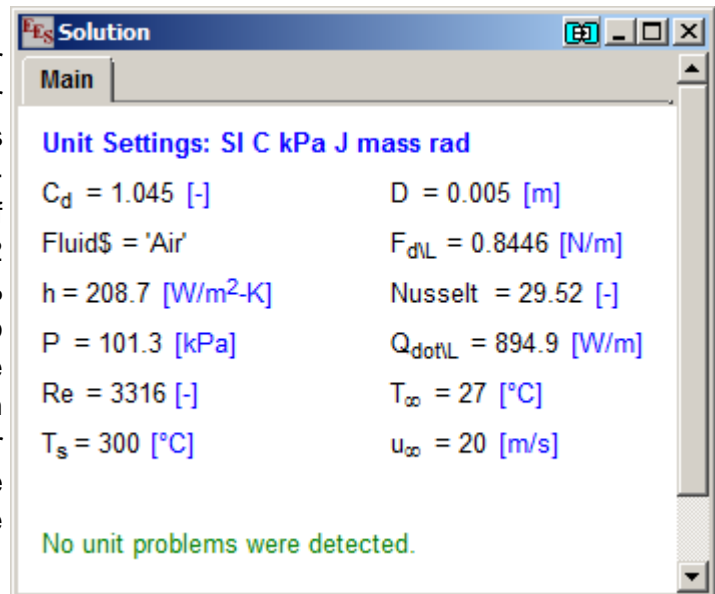
"wire diameter with  
"air velocity with ar  
"Air temperature +  
"Wire surface temp  
"atmospheric press  
"fluid"

Call External\_Flow\_Cylinder(Fluid\$, T\_infinity, T\_s, P, u\_infinity, D: F\_d/L, h, C\_d, Nusselt, Re)  
Q\_dot/L=h\*pi\*D\*(T\_s-T\_infinity) "heat transfer rate per length"



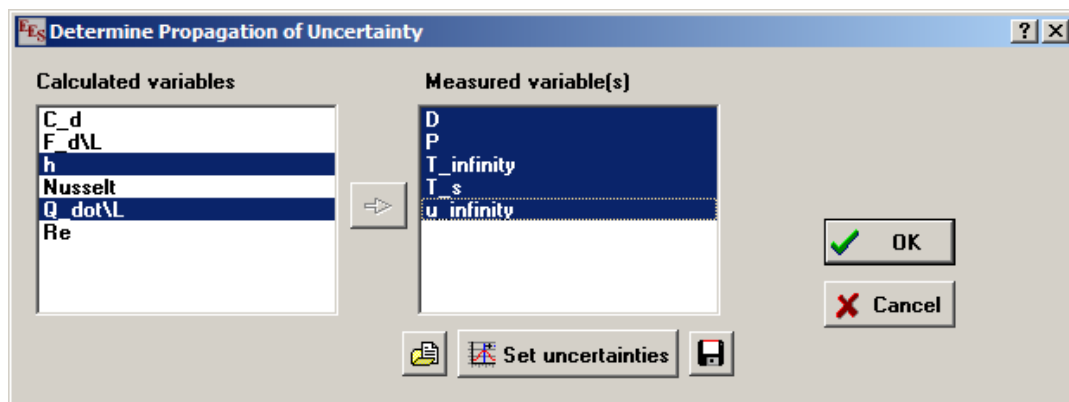
### Uncertainty Analyses Continued

Solving this EES code will result in a heat transfer coefficient of  $208.7 \text{ W/m}^2\text{-K}$  and a heat transfer rate of  $894.9 \text{ W/m}$ . However, the measurements used for this calculation are not perfect. The temperature measurements have an uncertainty of  $\pm 1 \text{ }^\circ\text{C}$ . The atmospheric pressure is known  $\pm 2 \text{ kPa}$  and the uncertainty in the air flow rate is 10% of its value. The diameter of the wire is known to within 50 microns. These uncertainties in the measured quantities affect the uncertainties in the heat transfer coefficient and the heat transfer rate. The uncertainty analysis in EES can be used to determine the uncertainties in these quantities.



EES needs to calculate the partial derivative of the calculated quantity with respect to each specified variable in order to determine the propagated uncertainty. The partial derivatives are often also useful to understand the sensitivity of the calculated variable to its various dependent variables. When the uncertainty analysis is carried out, EES reports the uncertainties and partial derivatives in the Solution window along with other information, as demonstrated below.

Select Uncertainty Propagation from the Calculation menu. Two lists of variables are shown in the dialog. The left list is used to select the variables for which uncertainty propagation is to be determined, i.e.,  $h$  and  $Q_{\dot{L}}$  in this case. The right list is used to select the measured variables that have uncertainty and are used to determine the calculated variables, i.e.,  $T_\infty$ ,  $T_s$ ,  $u_\infty$ ,  $D$ , and  $P$  for our problem.



Click the OK button in order to bring up the dialog window that allows the specification of the uncertainties in the measured variables.

## Uncertainty Analyses Continued

It is next necessary to specify the uncertainties of the measured variables. Click the Set Uncertainties button to bring up a dialog in which these uncertainties can be specified as absolute values or as a fraction of the measured values, as shown. Note that EES variables can be provided for the Absolute and Relative uncertainties, instead of numerical values.

**Uncertainties of Measured Variables** ? X

Enter a numerical value or variable name

Variable	Value	Units	Absolute Uncertainty	Relative Uncertainty
D	0.005	m	0.0005	
P	101.3	kPa	2	
T_infinity	27	°C	1	
T_s	300	°C	1	
u_infinity	20	m/s		0.1

Click the OK button in both dialogs to start the calculations. The results appear in the Solution window, as shown below.

**EES Solution** EES - [ ] X

Uncertainty Results | Solution

**Unit Settings: SI C kPa J mass rad**

Variable±Uncertainty	Partial derivative	% of uncertainty
<u>h = 208.7±14.94 [W/m<sup>2</sup>-K]</u>		
D = 0.005±0.0005 [m]	$\partial h / \partial D = -19903$	44.35 %
P = 101.3±2 [kPa]	$\partial h / \partial P = 1.079$	2.09 %
T <sub>∞</sub> = 27±1 [°C]	$\partial h / \partial T_{\infty} = -0.01958$	0.00 %
T <sub>s</sub> = 300±1 [°C]	$\partial h / \partial T_s = -0.01958$	0.00 %
u <sub>∞</sub> = 20±2 [m/s]	$\partial h / \partial u_{\infty} = 5.468$	53.56 %
<u>Q<sub>dotL</sub> = 894.9±67.13</u>		
D = 0.005±0.0005 [m]	$\partial Q_{dotL} / \partial D = 93799$	48.81 %
P = 101.3±2 [kPa]	$\partial Q_{dotL} / \partial P = 4.629$	1.90 %
T <sub>∞</sub> = 27±1 [°C]	$\partial Q_{dotL} / \partial T_{\infty} = -3.362$	0.25 %
T <sub>s</sub> = 300±1 [°C]	$\partial Q_{dotL} / \partial T_s = 3.194$	0.23 %
u <sub>∞</sub> = 20±2 [m/s]	$\partial Q_{dotL} / \partial u_{\infty} = 23.45$	48.81 %

No unit problems were detected.



## Uncertainty Analyses Continued

It is necessary for EES to determine the partial derivative of each calculated quantity with respect to each measured variable in order to do the uncertainty calculations. These partial derivatives are also displayed in the Solution window as they are often useful by themselves to show the sensitivity of the calculated variables to changes in the measured values. EES also determines the percent of the uncertainty that is attributed to each of the measured values and displays this information in the Solution window.

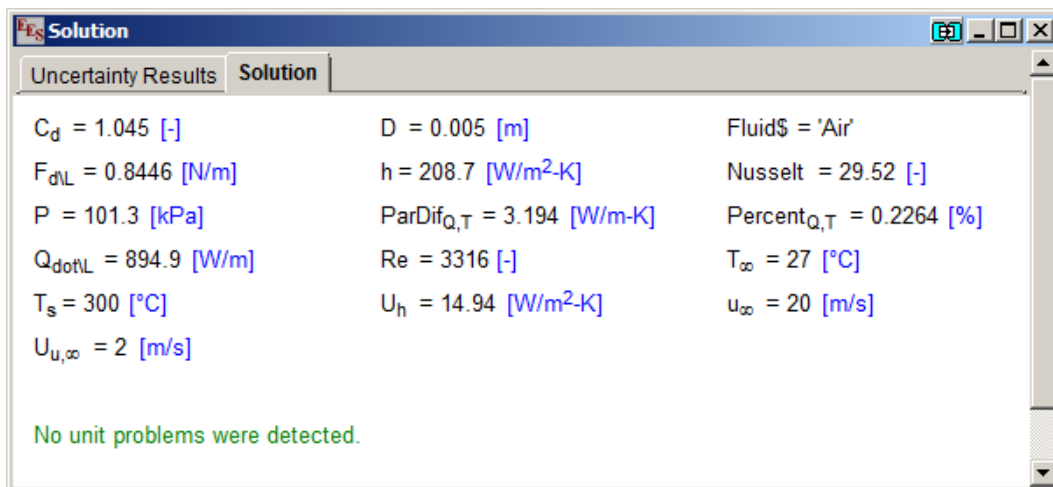
The values that are displayed in the Solution window can be moved into EES variables. As an example, add the following equations to the Equations window.

```

$If Uncertainty
  U_u_infinity=UncertaintyOf(u_infinity)           "specified uncertainty for u_infinity"
  U_h=UncertaintyOf(h)                            "propagated uncertainty in h"
  ParDif_Q_T=Uncert.ParDif(Q_dot\L,T_s)          "partial derivative of Q_dot with respect to T_s"
  Percent_Q_T=Uncert.Percent(Q_dot\L,T_s)        "percent of the total uncertainty in Q_dot attributed to the uncertainty in T_s"
$EndIf

```

Carrying out an uncertainty analysis (using the F6 shortcut key) will cause the variables  $U_u$ ,  $U_h$ ,  $ParDif_{Q,T}$ , and  $Percent_{Q,T}$  to be placed in the Solution window. These variables can be placed in a Parametric Table or used for other calculations.



A new capability in the Professional version is the ability to save and later retrieve uncertainty information. This capability is accessed with the buttons surrounding the Set uncertainties button in the Uncertainty Propagation dialog. Clicking the button on the right will bring up the Save Uncertainty Information dialog, which prompts you for the name of a file that has a .UNC file name extension. All of the specified uncertainty information will be saved in this file. This information includes all of the variables selected to be the calculation variables and the measured values with their associated uncertainties. Clicking the button on the left will bring up a file dialog in which any saved .UNC file can be retrieved. This capability allows you to have several different uncertainty analyses set up in one EES file without having to repeatedly enter the uncertainty information.



## Additional Changes to EES

- ThermalDiffusivity and KinematicViscosity have been added to the built-in property functions.
- Thermodynamic and transport data have been added for R40, diethylEther, HydrogenChloride, R1243zf, and orthoHydrogen.
- Lookup tables can be directly saved to and read from EXCEL .XLSX files with the Save Table and Open Lookup Table menu commands.
- The \$SaveVarInfo directive in the Professional version automatically saves EES variable information in a .VAR file after a successful calculation. This capability can be used with Distributable programs.
- A Reset button has been added to the Preferences dialog to set the preferences back to the as-shipped values.

## EES Training Opportunities

EES is used in many companies, organizations, and academic institutions. Most users are aware of the basic features—solving equations, Parametric Tables, plotting, and the powerful property routines. However, fewer users are aware of the more powerful features of EES such as optimization, integration, uncertainty propagation, complex algebra and subprograms. Even more advanced features available in the Professional version, such as the Diagram Window, animation, executables, web-based executables, directives, and macros, can enhance the capabilities of the program and open the door to a wide range of applications.

Our staff are available to provide a 1 day EES short course tailored to new users or experienced EES users. Contact Sandy Klein or Greg Nellis by email to arrange a training session ([info@fchart.com](mailto:info@fchart.com)).



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## Instant Update 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 and obtain technical support. 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 of the Service. Contact F-Chart Software if you wish to re-subscribe to the Instant Update Service.