Dealing with units and constants in EES version 7.441 (Handout version 5.0)

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EES variables can have units associated with them. Using these associated units, EES can check equations for dimensional consistency and appropriate unit conversions. To perform a units and dimensions check, use *Calculate* | *Check units* (or *F8*).

There are two ways to associate units with variables. A comment after the declaration of a variable can specify its units using the format "[*units*]", where *units* are the units of the quantity specified. However, some quantities are never explicitly defined in EES. These are variables that appear in equations and are to be solved for by EES. Use *Options* | *Variable information* to open a dialog box that permits the specification of units for these quantities.

Do not use the comment unit specification method to **change** the units associated with particular variables. At least some versions of EES did not seem to handle this situation correctly. It kept the previously defined units. The *Options* | *Variable information* approach should be used to change the units associated with a variable in these cases.

It appears that, in the current version of EES, built-in EES functions are aware of the units specified for variables and return values having units. This is a new feature and I've not thoroughly investigated it. If no units are specified, the functions use the units specified in the *Options* | *Unit system* dialog for both arguments and return values.

The units and dimensions recognized by EES are defined in the *units.txt* file in the main EES folder. Appendix A of this handout lists the dimensions and units defined in a previous version of the default *units.txt* file.

EES also contains a library of predefined constants. Constant names end with the # symbol. Constant are defined in the *constants.txt* file in the main EES folder. Appendix B of this handout lists the constants defined in a previous version of the default *constants.txt* file. The *Options* | *Constants* menu choice displays a table of predefined EES constants.

Menu choice *Options | Units conversion info*

Activate the units conversion information dialog and click on the dimension in the list at the left. All of the units which have been defined with that dimension are listed on the right. Note that only the defined units having the selected dimension are listed. For example, if you click on Area, only *acre*, *barn* and *hectares* will be displayed. However, any combination of units having the dimensions indicated at the top of the right list (e.g., L^2 for Area) can be used in the Convert function.

You can add additional units if needed by entering them into the *units.txt* file in the main EES directory. Instructions for adding information are provided at the top of the file.

Check Units Command

The Check Units command will check the dimensional and unit conversion consistency of all equations in the main part of the equations window. The equations in internal functions and procedures do not have units and are not checked. The results are reported in the Debug window.

It is necessary to enter the units of each variable for the checking process to function properly. The units can be entered in the *Options | Variable Info* dialog window or in the Solution window. The units of a variable set to a constant in the Equations window can also be set with in a comment by enclosing the units in square brackets. For example:

```
P=140 "[kPa]" {this equation will set P=140 and its units to kPa}
```

The checking algorithm cannot know the units of conversion constants, so it is best to avoid them in your equations. Instead, it is preferable to define constants or use the Convert function. For example, suppose you have two variables, L_inch and L_feet, whose units are set to inches and feet, respectively which are used in the following equation.

```
L_inch=L_feet*12
```

When the Check Units command is issued, the Debug window will appear and this equation will be flagged as having an error because the units of 12 are not known.

However, if the Convert function is employed as shown next, the equation will be accepted with no error.

```
L_inch=L_feet*convert(ft,in)
```

The Check Units command will display the equation and an explanatory message for each equation that is found to have dimensional consistency or unit consistency errors. If you click the left mouse button on an equation, the focus will jump to that equation in the Equations window. If you click the right mouse button on an equation, an abbreviate form of the Variable Information dialog window will appear showing just the variables that appear in that equation.

Convert Function

The *convert* function provides unit conversions. The format of the *convert* function is

```
convert('from', 'to')
```

where *from* and *to* are unit designations provided either as string constants or string variables. If string constants are used, the single quote marks are optional. String variables are identified with a $ as the final character in the variable name.

NOTE: The **CONVERT** function will convert temperature differences but it does NOT convert temperatures from one scale to another. Use the **CONVERTTEMP** function for this purpose.

The *convert* function returns the value X which satisfies the following relation:

```
From = X * To
```

As a specific example,

FI=Convert(ft^2, in^2)

will set FI to a value of 144 because 1 square foot is 144 square inches.

Combination of units and multiple unit terms may be entered. In a combination of units, such as Btu/hr-ft^2-R, the individual units are separated with a multiplication symbol (i.e., *), a dash (i.e., -) or division signs. Only a single division symbol may be used in any one term. All units to the right of the division symbol are assumed to be in the denominator (i.e., raised to a negative power). The ^ symbol is optional so ft2 and ft^2 are equivalent. The following example converts 5 Btu/hr-ft^2- into W/m2-K and sets H equal to this number:

```
H=5*Convert('Btu/hr-ft^2-R','W/m2-K)
```

The *convert* function will accept multiple unit terms. Each term is enclosed within parentheses. Terms are separated with an optional * symbol or with a / symbol, as in the example below.

```
P =15* Convert((lbm/ft3)*(ft)/(s^2/ft), kPa)
```

The defined unit symbols can be displayed with the Unit Conversion Info command in the Options menu.

If you find that a unit you need is not defined, you can enter it by editing the *units.txt* file in the EES directory. Instructions for entering new units are provided in the *units.txt* file.

The Convert function should be used in preference to constants that have inherent dimensions (e.g., 144 in^2/ft^2) in order to avoid false error reports from the *Solve | Check units* command.

Converttemp Function

The *ConvertTemp* function converts temperatures from one scale to another. Four scales are supported: Celsius (C), Kelvin (K), Fahrenheit (F), and Rankine (R). The *ConvertTemp* function has the following format:

```
ConvertTemp(from, to, temperature)
```

The first two parameters are string constants or string variables which must be *C*, *K*, *F*, or *R*. Both upper and lower case letters are permitted. The single quotes surrounding the string constants are permitted but not required. The third parameter is a temperature in the scale indicated by the first parameter. The function returns the temperature in the scale indicated by the second parameter.

Example:

```
TF=ConvertTemp('C', 'F', 100)
```

This statement will convert 100ºC to the equivalent temperature in ºF. The variable *TF* will be set to 212.

Use the *convert* function to convert differences in temperature from one scale to another.

Greek Characters

If the Show Subscripts and Greek Symbols option in the Preferences dialog is selected, then EES variables having Greek alphabet names will be displayed as Greek symbols. If the variable name consists entirely of capital letters and if the upper case Greek symbol differs from the Arabic letter, then the upper case Greek symbol will be displayed; otherwise the lower case Greek symbol will be displayed. The following table indicates the conversion:

Variable Name	Upper case	Lower Case
ALPHA	α	α
BETA	β	β
CHI	χ	χ
DELTA	Δ	δ
EPSILON	ε	ε
PHI	Φ	ϕ
GAMMA	Γ	γ
ETA	η	η
IOTA	ι	ι
JTHETA	ϑ	φ
KAPPA	κ	κ
LAMBDA	Λ	λ

MU	μ	μ
NU	ν	ν
THETA	Θ	θ
RHO	ρ	ρ
SIGMA	Σ	σ
TAU	τ	τ
UPSILON	υ	υ
OMEGA	Ω	ω
XI	Ξ	ξ
PSI	Ψ	ψ
ZETA	ζ	ζ

Special Symbols

To enter these symbols, hold the Alt key down and enter the three digits on the numeric keypad with NumLock engaged:

µ Alt-230
± Alt-241
÷ Alt-246
° Alt-248

Formatting Additions to Enhance Variable Display

X_1 will display as X with a subscript 1
X_bar will display with a bar centered above the X
X_dot will display with a dot centered above the X
X_ddot will display with a double-dot centered above the X
X_hat will display with a hat (^) centered above the X
X|star will display as X*
X|plus will display as X superscript+
x|o will display as X subcript o

Note: much of the material in this handout was taken from the EES help pages.

Appendix A – EES Default Units (from *units.txt*)

The basic dimensions and the selected unit for each dimension are:

L	Length	m
M	Mass	kg
N	Moles	kmole
T	Time	sec
D	Temperature difference	K
A	Angle	radian
C	Charge	coulomb

You may enter additional unit definitions to this file. To do so, enter the unit name followed by its conversion factor into the selected set of dimensions indicated above separated with one or more spaces. Designate a new dimension type by preceding the description with a $ and provide the basic dimensions in parentheses.

$Length (L)
m 1
meter 1
metre 1
Angstrom 1E-10
nm 1E-9
ft 0.3048
dm 0.1
in 0.0254
inch 0.0254
mm 0.001
micron 1e-6
micrometer 1e-6
µm 1e-6
nanometer 1e-9
millimeter 0.001
cm 0.01
km 1000
yd 0.9144
yard 0.9144
mile 1609.344
fathom 1.8288
mil 0.0000254
rod 5.0292
furlong 201.168
league 5556
hectometer 100

$Mass (M)
kg 1
lbm 0.453592374
lb_m 0.453592374
g 0.001
ton 907.184749
grain 6.4799e-5
mg 1e-6
oz 0.028349523
ozm 0.028349523
slug 14.593881
stone 6.350293236
amu 1.660531E-27

$Moles (N)
kgmole 1
kgmol 1
kmole 1
kmol 1
lbmole 0.453592374
lbmol 0.453592374
gmole 0.001
gmol 0.001
mole 0.001
mol 0.001

$Time (T)
s 1
sec 1
second 1
min 60
minute 60
h 3600
hr 3600
hour 3600
day 86400
days 86400
week 604800
weeks 604800
fortnight 1.2096E6
year 31.536E6
yr 31.536E6
years 31.536E6

$Frequency (1/T)
cps 6.28318530718
cpm 0.10471975512
Bq 6.28318530718
ci 23.2477856e10
Hz 6.28318530718
rps 6.28318530718
rpm 0.10471975512

$Temp. Difference (D)
K 1
C 1
R 0.55555556
F 0.55555556
°C 1

°F 0.55555556

$Velocity (L/T)
mph 0.44704
knot 0.51444

$Area (L^2)
acre 4046.856
hectare 10000
barn 1e-28

$Volume (L^3)
gal 0.0037854118
l 0.001
Bu 3.523007016688e-2
ml 1e-6
liter 0.001
quart 0.0009463264
oz 2.9572702e-5
ozv 2.9572702e-5
pint 0.000473163

$Volumetric flow (L^3/T)
cfm 0.47194744E-3
gph 1.051503E-6
gpm 6.30902E-5

$Force (M-L/T^2)
N 1
kN 1000
lbf 4.448222
lb_f 4.448222
dyne 1E-5

$Pressure (M/L-T^2)
Pa 1
milliPa 1E-3
microPa 1E-6
kPa 1000
MPa 1E6
GPa 1E9
gigaPa 1E9
bar 1E5
milliBar 1E2
atm 1.01325E5
psia 6894.75788958
psi 6894.75788958
ksi 6894757.88958
psig 6894.75788958
psf 47.88055555
mmH2O 9.806614
mmHg 133.3224
inHg 3386.388
torr 133.3224
inH2O 249.088
in.H2O 249.088
ftH2O 2989.057

$Energy (M-L^2/T^2)
milliJ 1E-3
J 1
kJ 1000
MJ 1E6
kWh 3.6E6
kWhr 3.6E6
GJ 1E9
Btu 1055.056
MBtu 1055056.0
MMBtu 1055056000.0
kBtu 1055056.0
cal 4.1868
kcal 4186.8
erg 1E-7
ev 1.60207E-19
kev 1.60207E-16
mev 1.60207E-13
bev 1.60207E-10
therm 105505600
therms 105505600

$Power (M-L^2/T^3)
W 1
hp 745.700
ton 3516.852
tons 3516.852
microW 1E-6
milliW 1E-3
kW 1000
MW 1E6
MegaW 1E6
gW 1E9
gigaW 1E9

$Viscosity-dynamic (M/L-T)
poise 0.1
centipoise 0.001
micropoise 1E-7
cp 0.001
Reyn 6894.7

$Viscosity-kinematic (L^2/T)
Stoke 1E-4
centiStoke 1E-6

$Angles (A)
radian 1
radians 1
rad 1
deg 0.017453293
degree 0.017453293
degrees 0.017453293
° 0.017453293
rev 6.28318530718
revs 6.28318530718
revolutions 6.28318530718
minute 2.90888E-4
quadrant 1.5707963
cycle 6.28318530718
cycles 6.28318530718

$Charge (C)
Coulomb 1
Faraday 96517.844
Abcoulomb 10

$Electrical Capacitance (C^2-T^2/M-L^2)
Farad 1

$Dipole Moment (C-L)
Debye 3.33564e-30

$Current (C/T)
Amp 1

Ampere 1
A 1

$Electrical Resistance (M-L^2/T-C^2)
ohm 1
kohm 1000

$Electromotive Force (M-L^2/T^2-C)
Volt 1
millivolt 0.001
kV 1000
MegaVolt 1E6
v 1

$Inductance (M-L^2/C^2)
Henry 1

$Cost ($)
#$ 1
cents 0.01

$Non Dimensional ( )
Percent 0.01
% 0.01
person 1
persons 1

$Magnetic Flux Density (M/T-C)
Gauss 1E-4
G 1E-4
Tesla 1
T 1

$Magnetic Flux (M-L^2/T-C)
Maxwell 1E-8
Mx 1E-8
Weber 1
Wb 1

$Magnetic Field Strength (C/T-L)
Oersted 79.5774715459
Oe 79.5774715459

Appendix B – EES Default Constants (from *constants.txt*)

The default *constants.txt* file contains the following definitions:

```
//Name [tab] Description [tab] SIValue [tab] SIUnits [tab] EngValue [tab], EngUnits
h_C3H6_g#	Propylene (gas) enthalpy of formation (25C, 77F)	-20410	kJ/kmol	-8.774720E+03	Btu/lbmol
h#	Planck's constant	6.626196e-34	J-s	6.280421E-37	Btu-s
Mp#	Proton rest mass	1.672614e-27	kg	3.687483E-27	lb_m
Vo#	Volume of ideal gas, standard conditions	2.24136e1	m^3/kmol	3.590314E+02	ft^3/lbmol
R_inf#	Rydberg constant	1.097373e7	1/m	3.344793E+06	1/ft
Po#	Normal atmospheric pressure	101.325	kPa	1.469594E+01	psia
h_CH3OH_l#	Methanol (liq) enthalpy of formation (25C, 77F)	-238660	kJ/kmol	-1.026053E+05	Btu/lbmol
h_CH3OH_g#	Methanol (gas) enthalpy of formation (25C, 77F)	-200670	kJ/kmol	-8.627257E+04	Btu/lbmol
h_C8H18_g#	n-Octane (gas) enthalpy of formation (25C, 77F)	-208450	kJ/kmol	-8.961737E+04	Btu/lbmol
Mn#	Neutron rest mass	1.674920e-27	kg	3.692567E-27	lb_m
h_C8H18_l#	n-Octane (liq) enthalpy of formation (25C, 77F)	-249950	kJ/kmol	-1.074591E+05	Btu/lbmol
Blue#	the color blue	16711680		16711680
U#	Unified atomic mass unit	1.660531e-27	kg	3.660845E-27	lb_m
C#	Speed of light in a vacuum	2.9979250e8	m/s	9.835712E+08	ft/s
Yellow#	the color yellow	65535		65535
Green#	the color green	65280		65280
h_fg_water#	Enthalpy of vaporization of water (25C, 77F)	2441.5	kJ/kg	1.049656E+03	Btu/lb_m
G_sc#	Solar constant	1367	W/m^2	433	Btu/ft^2-hr
SndSpeed#	speed of sound in dray air at 0 C and 1 atm	331.36	m/s	1089	ft/s
T_zero#	T_zero# + C (or F) = K (or R)	273.15	K	459.67	R
sigma#	Stefan-Boltzmann constant	5.66961e-8	W/m^2-K^4	1.712065E-09	Btu/hr-ft^2-R^4
h_H2O2#	Hydrogen peroxide (gas) enthalpy of formation (25C, 77F)	-136310	kJ/kmol	-5.860275E+04	Btu/lbmol
R#	Gas constant	8.31434	kJ/kmol-K	1.985846	Btu/lbmol-R
r_e#	Classical electron radius	2.817939e-15	m	9.245207E-15	ft
h_CH2#	Acetylene enthalpy of formation (25C, 77F)	226730	kJ/kmol	9.747635E+04	Btu/lbmol
gc#	Gravitational constant	6.6732e-11	N-m^2/kg^2	3.3224e-11	lb_f-ft^2/lb_m^2
k#	Boltzmann's constant	1.380622e-23	J/K	7.269872E-27	Btu/R
C1#	Blackbody radiation constant 1	3.7420e8	W-micrometer^4/m^2	1.187e8	Btu-micrometer^4/hr-ft^2
h_C6H6#	Benzene (gas) enthalpy of formation (25C, 77F)	82930	kJ/kmol	3.565348E+04	Btu/lbmol
e#	Electron charge	1.6021917e-19	Coulomb	1.6021917e-19	Coulomb
h_NH3#	Ammonia (gas) enthalpy of formation (25C, 77F)	-46190	kJ/kmol	-1.985812E+04	Btu/lbmol
NA#	Avogadro's constant	6.022169e26	1/kmol	6.022169e26	1/lbmol
F#	Faraday's constant	9.648670E7	Coulomb/kmol	4.376563E7	Coulomb/lbmol
g#	Gravitational acceleration (sea level)	9.807	m/s^2	3.217520E+01	ft/s^2
h_C2H4#	Ethylene enthalpy of formation (25C, 77F)	52280	kJ/kmol	2.247635E+04	Btu/lbmol
h_C2H5OH_l#	Ethanol (liq) enthalpy of formation (25C, 77F)	-277690	kJ/kmol	-1.193852E+05	Btu/lbmol
C2#	Blackbody radiation constant 2	1.4388e4	micrometer-K	2.5897e4	micrometer-R
e\Me#	Electron charge to mass ratio	1.7588028e11	Coulomb/kg	7.977796E+10	Coulomb/lb_m
C3#	Blackbody radiation constant 3	2897.7	micrometer-K	5215.6	micrometer-R
Red#	red	255		255
```

Me#	Electron rest mass	9.109558e-31	kg	2.008314E-30	lb_m
h_C2H5OH_g#	Ethanol (gas) enthalpy of formation (25C, 77F)	-235310	kJ/kmol	-1.011650E+05	Btu/lbmol
White#	the color white	16777215		16777215	
Black#	the color black	0		0	
false#	true# and false# are used in logic tests	0		0	
true#	true# and false# are used in logic tests	1		1	