EES Solution for Example Problem – Matching a Pump to a Piping System

Here is exactly what I typed into the main "Equations Window" of EES:

Equations Window

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"EES Solution for the class example problem - matching a pump to a piping system
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"Constants:"

Deltaz = 8.0 [m]
rho = 1000 [kg/m^3]
mu = 1.00e-3 [kg/(m*s)]
D = 0.022 [m]
L = 150 [m]
SigmaK_L = 0.5 + 10 + 3*0.9 + 1.05
epsilon = 0.00026 [m]
g = g# "(gravitational constant, predifined by EES)"

"Pump performance curve:"

H_0 = 20.0 [m]
a_pump = 2.592e8 [s^2/m^5]

"Equations:"

Re = (rho*D*V)/mu
V_dot = V*PI*(D^2)/4
h_pump_u_supply = H_0 - a_pump*V_dot^2
h_pump_u_system = 8*V_dot^2/(PI^2*g*D^4)*(f*L/D + SigmaK_L) + Deltaz
h_pump_u_supply = h_pump_u_system
V_dot_LPM = V_dot*Convert(m^3/s,L/min)
"Colebrook equation:"    1/sqrt(f) = -2.0*log10((epsilon/D)/3.7 + 2.51/(Re*sqrt(f)))

"To solve, click on Calculate and then Solve. Note that it does not converge unless you
..change the limits and guesses in Options-Variable Info"
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Here is what the Formatted Equations window looks like (much “cleaner” looking equations – and easier to spot typo errors):

$$\delta z = 8 \quad [m]$$

$$\rho = 1000 \quad [kg/m^3]$$

$$\mu = 0.001 \quad [kg/(m*s)]$$

$$D = 0.022 \quad [m]$$

$$L = 150 \quad [m]$$

$$SigmaK_L = 0.5 + 10 + 3 \cdot 0.9 + 1.05$$

$$\varepsilon = 0.00026 \quad [m]$$

$$g = 9.807 \quad [m/s^2] \quad \text{(gravitational constant, predifined by EES)}$$

Pump performance curve:

$$H_0 = 20 \quad [m]$$

$$a_{pump} = 2.592 \times 10^8 \quad [s^2/m^5]$$

Equations:

$$Re = \frac{\rho \cdot D \cdot V}{\mu}$$

$$\dot{V} = V \cdot \pi \cdot \frac{D^2}{4}$$

$$h_{pump,u,supply} = H_0 - a_{pump} \cdot \dot{V}^2$$

$$h_{pump,u,system} = 8 \cdot \frac{\dot{V}^2}{\pi^2 \cdot g \cdot D^4} \cdot \left[f \cdot \frac{L}{D} + SigmaK_L \right] + \delta z$$

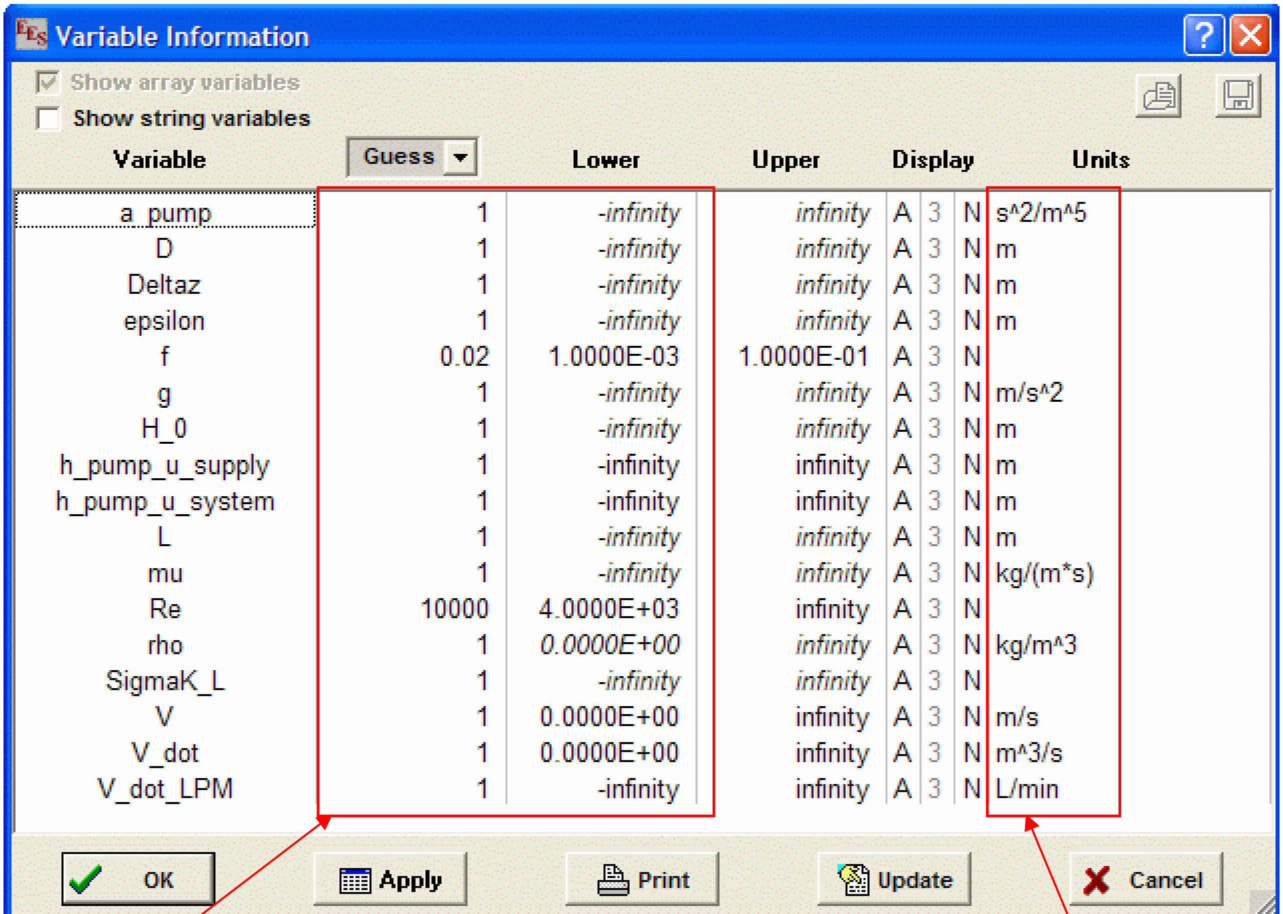
$$h_{pump,u,supply} = h_{pump,u,system}$$

$$\dot{V}_{LPM} = \dot{V} \cdot \left| 60000 \cdot \frac{L/min}{m^3/s} \right|$$

Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2 \cdot \textbf{log} \left[\frac{\varepsilon}{D \cdot 3.7} + \frac{2.51}{Re \cdot \sqrt{f}} \right]$$

Here is what the “Options-Variable Info” chart looks like:

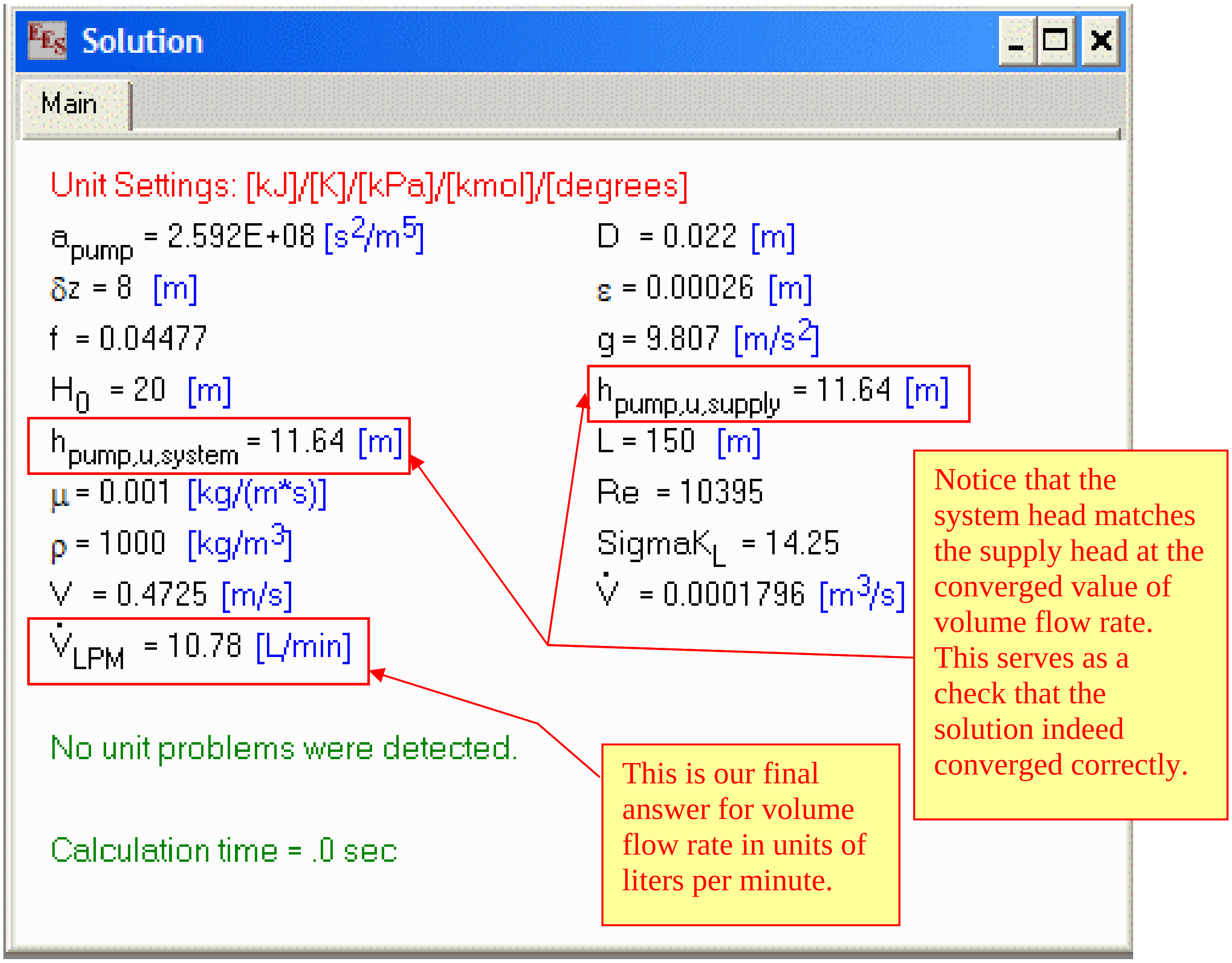


Variable	Guess	Lower	Upper	Display			Units
a_pump	1	-infinity	infinity	A	3	N	s^2/m^5
D	1	-infinity	infinity	A	3	N	m
Deltaz	1	-infinity	infinity	A	3	N	m
epsilon	1	-infinity	infinity	A	3	N	m
f	0.02	1.0000E-03	1.0000E-01	A	3	N	
g	1	-infinity	infinity	A	3	N	m/s^2
H_0	1	-infinity	infinity	A	3	N	m
h_pump_u_supply	1	-infinity	infinity	A	3	N	m
h_pump_u_system	1	-infinity	infinity	A	3	N	m
L	1	-infinity	infinity	A	3	N	m
mu	1	-infinity	infinity	A	3	N	kg/(m*s)
Re	10000	4.0000E+03	infinity	A	3	N	
rho	1	0.0000E+00	infinity	A	3	N	kg/m^3
SigmaK_L	1	-infinity	infinity	A	3	N	
V	1	0.0000E+00	infinity	A	3	N	m/s
V_dot	1	0.0000E+00	infinity	A	3	N	m^3/s
V_dot_LPM	1	-infinity	infinity	A	3	N	L/min

Note: I had to change some of the initial guesses and some of the lower and upper limits in order for EES to converge on a solution. This takes some trial and error.

I also had to manually insert some of the units. It seems that EES is not smart enough to calculate the units on its own.

Finally, Calculate and Solve yields the solution, as shown in the Solution window:



Note: It is also possible to plot with EES. Here is a plot of supply head and system head as functions of volume flow rate. As you can see, they intersect at the operating point, which is around 10.8 Lpm.