# EES Solution for Example Problem – Parallel Pipe Network and Pump Bypass

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

Equations Window

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"EES solution for the pump bypass in-class example problem, ME 33.
Problem developed by Eric G. Paterson, March 2005, and modified by John M. Cimbala, March 2005."

"Constants:"

rho = 998 [kg/m^3]                    "density of the fluid"
mu = 1.00e-3 [kg/(m*s)]               "viscosity of the fluid"
g = g#                                "gravitational constant, a predefined constant in EES"
V_dot_d = 0.20 [m^3/s]                "desired downstream volume flow rate (to be kept constant)"

L_p = 3.0 [m]                         "pipe length for the pump line"
L_b = 5.0 [m]                         "pipe length for the bypass line"
D_p = 0.5 [m]                         "pipe diameter for the pump line"
D_b = 0.5 [m]                         "pipe diameter for the bypass line"
epsilon_p = 0.002 [m]                 "average roughness height of the pump line pipe"
epsilon_b = 0.002 [m]                 "average roughness height of the bypass line pipe"
SigmaK_p = 0                          "minor losses in the pump line (there are none)"
SigmaK_b = 2*1.0 + 2*0.2 + K_L_valve  " minor losses in the bypass line (two branch tees, two elbows, and one valve)"
         "K_L_valve = 0.4"                 "remove the quotes in the equation to the left to test at one K_L_valve"

"NOTE: The above equation for SigmaK_b is the only place in the Equations Window in which variable K_L_valve appears. This is
..because we are going to construct a parametric table in which K_L_valve varyies over a range of values. All the other variables will
..then be solved by EES for each value of K_L_valve in the parametric table, and a plot will be generated."


"Pump performance curve (supply curve), as provided by the pump manufacturer:"

a = 100 [m]                                "pump performance constant 1"
b = 1.0                                    "pump performance constant 2"
c = 1.0 [s^2/m^6]                          "pump performance constant 3"
h_pump_u_supply = a*(b-c*V_dot_p^2)        "useful pump head supplied by the pump"


"Equations:"

V_dot_p = V_dot_b + V_dot_d                "conservation of mass equation"
V_dot_p = V_p*PI*D_p^2/4                   "volume flow rate in the pump line"
V_dot_b = V_b*PI*D_b^2/4                   "volume flow rate in the bypass line"
h_L_p = (f_p*L_p/D_p + SigmaK_p)*V_p^2/(2*g)   "irreversible head loss in the pipe line"
h_L_b = (f_b*L_b/D_b + SigmaK_b)*V_b^2/(2*g)   "irreversible head loss in the bypass line"
h_pump_u_system = h_L_b + h_L_p            "useful pump head required for the system"
Re_p = rho*D_p*V_p/mu                      "Reynolds number in the pipe line"
Re_b = rho*D_b*V_b/mu                      "Reynolds number in the bypass line"
h_pump_u_system = h_pump_u_supply          "conservation of energy equation (combination of two CVs)"
1/sqrt(f_p) = -2.0*log10(epsilon_p/D_p/3.7 + 2.51/Re_p/sqrt(f_p))      "Colebrook equation for pump line"
1/sqrt(f_b) = -2.0*log10(epsilon_b/D_b/3.7 + 2.51/Re_b/sqrt(f_b))      "Colebrook equation for bypass line"
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I created a parametric table, and selected four of the variables (Table-New Parametric Table):

Parametric Table

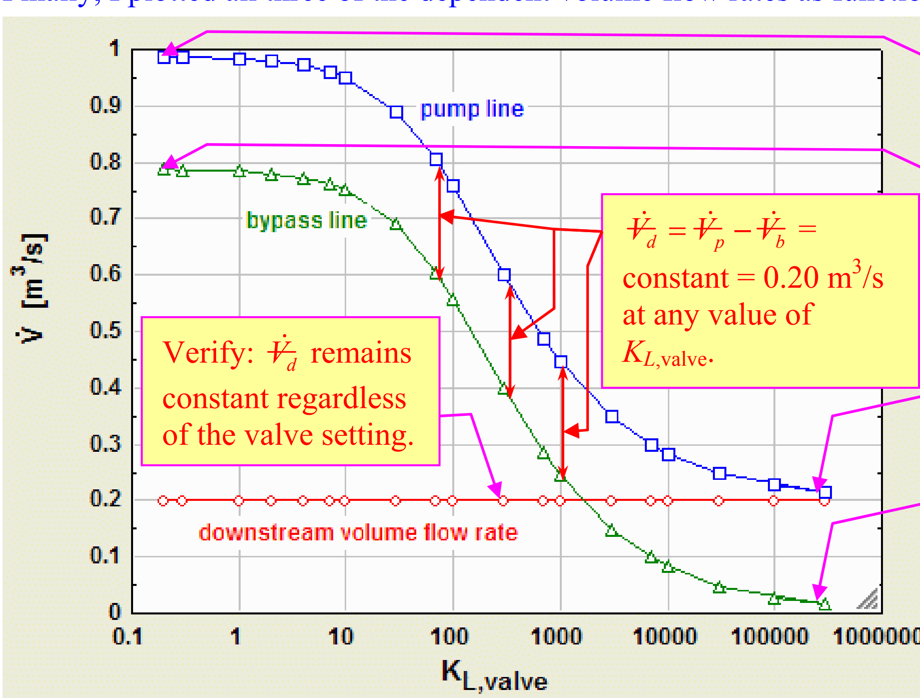
Table 1

| 1..20 | $K_{L,valve}$ | $\dot{V}_p$ [m3/s] | $\dot{V}_d$ [m3/s] | $\dot{V}_b$ [m3/s] |
|---|---|---|---|---|
| Run 1 | 0.2 | 0.987 | 0.2 | 0.787 |
| Run 2 | 0.3 | 0.9866 | 0.2 | 0.7866 |
| Run 3 | 1 | 0.9838 | 0.2 | 0.7838 |
| Run 4 | 2 | 0.9799 | 0.2 | 0.7799 |
| Run 5 | 4 | 0.9722 | 0.2 | 0.7722 |
| Run 6 | 7 | 0.9611 | 0.2 | 0.7611 |
| Run 7 | 10 | 0.9505 | 0.2 | 0.7505 |
| Run 8 | 30 | 0.8901 | 0.2 | 0.6901 |
| Run 9 | 70 | 0.8045 | 0.2 | 0.6045 |
| Run 10 | 100 | 0.7584 | 0.2 | 0.5584 |
| Run 11 | 300 | 0.5997 | 0.2 | 0.3997 |
| Run 12 | 700 | 0.4865 | 0.2 | 0.2865 |
| Run 13 | 1000 | 0.4458 | 0.2 | 0.2458 |
| Run 14 | 3000 | 0.3487 | 0.2 | 0.1487 |
| Run 15 | 7000 | 0.2991 | 0.2 | 0.09915 |
| Run 16 | 10000 | 0.2834 | 0.2 | 0.08337 |
| Run 17 | 30000 | 0.2486 | 0.2 | 0.04862 |
| Run 18 | 300000 | 0.2155 | 0.2 | 0.0155 |
| Run 19 | 100000 | 0.2268 | 0.2 | 0.02678 |
| Run 20 | 300000 | 0.2155 | 0.2 | 0.0155 |

I specified the values of $K_{L,\text{valve}}$, ranging from the minimum of 0.2 (fully open gate valve) to a very large number (valve nearly closed).

The rest of the values are automatically calculated and filled in when you click on the green arrow at the upper left.

Finally, I plotted all three of the dependent volume flow rates as functions of $K_{L,\text{valve}}$:




When the valve is fully open, we get the maximum flow rate through both the pump and bypass lines.

When the valve is nearly closed, there is hardly any flow through the bypass line – nearly all the flow is through the pump line.