Name: _____

CVEN 458 – Hydraulic Engineering of WDS
Spring Semester 2010
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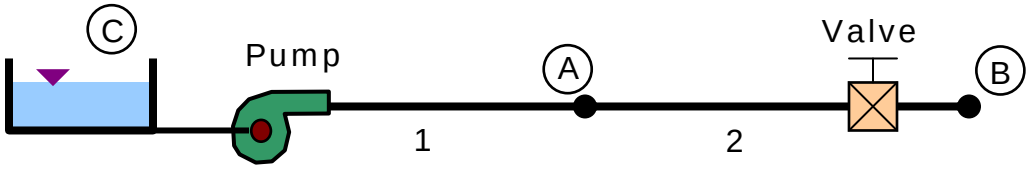
Exam #1

Open-book, Open-notes (6 pages, 3 questions); Time allowed: 75 minutes

1. Drawn below is a small water distribution system that includes a significant valve in pipe 2.



(a) *Write the complete set of node and pipe equations for this system.* All equations should be in the "generic" form with no assumptions made on head loss formula and head loss sign correctly computed from negative flows. (15 points)

(b) *Write the matrices for the Newton's method implementation for this system.* Remember that the Newton's method implementation (part of the Gradient Method) is the matrix equation:

$$\begin{bmatrix} n\underline{A_{11}} & \underline{A_{12}} \\ \underline{A_{21}} & \underline{0} \end{bmatrix} \times \begin{bmatrix} \underline{\Delta Q} \\ \underline{\Delta H} \end{bmatrix} = \begin{bmatrix} -\underline{dE} \\ -\underline{dq} \end{bmatrix}$$

In your answer, explicitly state all individual matrix elements. For the $\underline{A_{21}}$ and $\underline{A_{12}}$ elements, you should write 0, -1, or +1, as appropriate. For the $\underline{A_{11}}$, $\underline{dE}$, and $\underline{dq}$ elements, you should write the appropriate mathematical expression with variables – e.g., "$x^2 + By - z^{0.5}$". Thus, your final answer should like something like:

$$\begin{bmatrix} 3x^2 + y & 0 & 0 \\ 1 & +1 & -1 \\ 0 & 1 & 0 \end{bmatrix} \times \begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta H_1 \end{bmatrix} = \begin{bmatrix} 2z - y \\ x + y \\ y^2 \end{bmatrix}$$

(30 points)

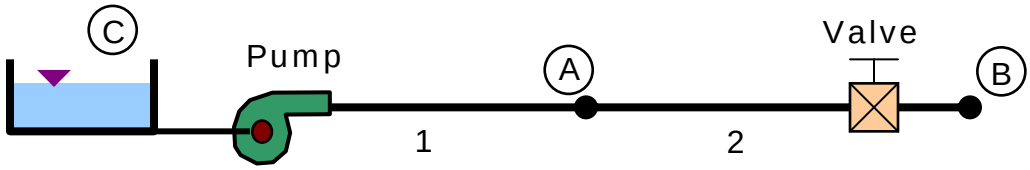
2. The WDS from problem 1 is drawn again below. For the numerical values of system properties given below, *do all necessary work to setup the first iteration of the Gradient Method solution for flows and heads in this network.* Your final answer should be the matrix equation:

$$\begin{bmatrix} n\underline{A_{11}} & \underline{A_{12}} \\ \underline{A_{21}} & \underline{0} \end{bmatrix} \times \begin{bmatrix} \underline{\Delta Q} \\ \underline{\Delta H} \end{bmatrix} = \begin{bmatrix} -\underline{dE} \\ -\underline{dq} \end{bmatrix}$$

with all matrices fully written out including numerical values where possible. That is, your final answer should look something like:

$$\begin{bmatrix} 3 & 0 & 0 \\ 1 & 2 & -1 \\ 0 & 1 & 1 \end{bmatrix} \times \begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta H_1 \end{bmatrix} = \begin{bmatrix} 21.3 \\ -9.6 \\ -0.53 \end{bmatrix}$$

You may begin your work for this problem with the results of problem 1. You should use the Hazen-Williams equation for pipe flow head loss. (30 points)



Node	Demand (gpm)	Elevation (ft)	Head (ft)	Pipe	Length (ft)	Diameter (in)	Roughness, *C*
A	100	100	–	1	100	6	105
B	200	50	–	2	150	4	100
C	–	–	150				

Pump characteristic equation: $E_p = (-5.55 \cdot 10^{-5})Q^2 + (-0.0167)Q + 150$, $[E_p]$ = ft, $[Q]$ = gpm

Valve minor loss coefficient: $K_M = 5.6$

Hazen-Williams Eqn: $Q = 0.281\, C\, D^{2.63} \left(\frac{H_f}{L} \right)^{0.54}$, for $[Q]$ = gpm, $[D]$ = in, $[H_f, L]$ = ft

{Work space for #2}

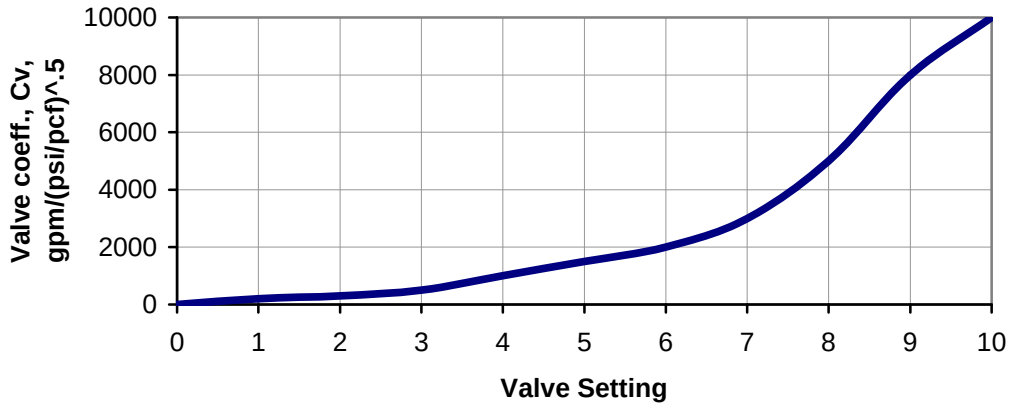
3. For the same WDS as has been discussed in problems 1 and 2…

The valve installed on pipe 2 is a gate valve. The manufacturer publishes the following spec sheet for the valve:

Aggie Valve Model G-10

The model G-10 gate valve is manually operated and includes a valve setting indicator with continuous readout of the valve's status ("0" = fully closed, "10" = fully open).

Pressure drop through the valve can be calculated from the valve coefficient C_V that varies with valve setting: $P_D = \frac{\gamma}{C_V^2} Q^2$, where P_D = pressure drop (psi), γ = specific weight of fluid (62.4 lb/ft^3, a.k.a., pcf), Q = flowrate (gpm), and C_V = valve coefficient (gpm/[psi/pcf]$^{1/2}$ determined from the chart below:



You are to write an operations manual for the WDS that includes valve setting instructions to maintain pressure at node B within acceptable values. *Determine the acceptable range of valve settings to meet the pressure requirements at node B.* E.g., an acceptable range of valve settings would be expressed as "5.1 to 8.2" to mean that the valve should not be closed below the 5.1 setting and should not be opened above the 8.2 setting. (25 points)

Node B acceptable pressure range: 90 to 100 psi

{Work space for #3}