40.9 **$50gpm$ of cold water at $60°F$ enters a $100ft$ tall building via $3in$ schedule 40 steel supply piping. Street pressure prior to the service entrance to the building is $85psig$. The equivalent length of piping on the longest run to the top floor is $500ft$. What pressure is available to fixtures on the top floor?**

A. $40psig$

B. $42psig$

C. $45psig$

D. $55psig$

Start by writing the Bernoulli Equation:

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_f$$

where P is static pressure, v is velocity, z is height, and h_f is friction loss. Neglecting the velocity term which makes a negligible contribution in many problems involving comparatively large static pressures and heights, and rearranging to solve for the unknown P_2 on the top floor of the building:

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + (z_1 - z_2) - h_f$$

Note the specific weight, $\gamma = \rho g$; however, at the end of the problem we will use a rule of thumb for water which saves time.

The street pressure P_1 is given and the Δz is known based on the height of the building. The main effort of the problem is finding the losses, h_f, using the Darcy Equation.

$$h_f = \frac{fLv^2}{2gD}$$

Using the Steel Pipe Friction Tables, the diameter of a nominal 3 inch pipe and the velocity of $50gpm$ through the pipe can be gathered:

$$D = \frac{3.068in}{12\frac{in}{ft}} = 0.2557ft$$

$$@50pgm : V = 2.17\frac{ft}{sec}$$

Calculate the Reynolds Number. Lookup the Kinematic Viscosity of water $@T = 60°F$ by searching for Properties of Water.

$$Re = \frac{vD}{\nu} = \frac{\left(2.17\frac{ft}{sec}\right)(0.2557ft)}{\left(1.217 \times 10^{-5}\frac{ft^2}{sec}\right)} = 45,600$$

Find the Relative Roughness. Values for ϵ for standard weight steel are shown on the Moody Diagram. It is fine to round off the diameter since the Moody Diagram provides limited precision.

$$\frac{\epsilon}{D} = \frac{0.0002ft}{0.25ft} = 0.0008$$

Read the friction factor from the Moody Diagram.

$$f = f\left(Re, \frac{\epsilon}{D}\right) \approx 0.023$$

Determine the pressure losses. Be sure to use the equivalent length for L.

$$h_f = \frac{fLv^2}{2gD} = \frac{(0.023)(500ft)\left(2.17\frac{ft}{sec}\right)^2}{2(0.2557ft)\left(32.2\frac{ft}{sec^2}\right)} = 3.3ft$$

Use the rule of thumb conversion factor for water $2.31\frac{ft}{psi}$ for convenience converting between pressure units and feet of head. As a reminder, this rule of thumb comes from dividing by the specific weight, γ, and converting from ft^2 to in^2at the same time. The rule of thumb applies only to water, as any substance with a non-unity specific gravity will have a different conversion.

$$\frac{144\frac{in^2}{ft^2}}{62.4\frac{lb_f}{ft^3}} = 2.31\frac{ft \cdot in^2}{lb_f} = 2.31\frac{ft}{psi}$$

Determine P_2. Note that $\Delta z = z_1 - z_2$ as written has a negative value since $z_2 > z_1$ due to being higher in the building.

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + (z_1 - z_2) - h_f = (85psi)\left(2.31\frac{ft}{psi}\right) + (0ft - 100ft) - 3.3ft = 93.05ft$$

$$\frac{P_2}{\gamma} = 93.05ft \rightarrow P_2 = \frac{93.05ft}{2.31\frac{ft}{psi}} = 40.3psig$$

Note the street pressure was given in psig and the answer choices are in psig, and since it is a continuous system there is no need to convert to psia at any point.

Answer A