Calculate the friction loss by solving the Darcy equation:

$$h_f = \frac{fLv^2}{2gD} = \frac{(0.0165)(100ft)\left(5.13\frac{ft}{s}\right)^2}{2(0.6651ft)\left(32.2\frac{ft}{s^2}\right)} = 1.01ft$$

Answer A

40.12 $200gpm$ **of** $90°F$ **water flows through** $500ft$ **of** $4in$ **nominal schedule 40 steel pipe, with a discharge that is** $30ft$ **higher than the entrance. The pipe contains the following flanged welded pipe fittings: (4) 90° elbows, (2) 90° long radius elbows, (2) gate valves, and (1) globe valve. What is the pressure difference between the two ends of the pipe?**

A. $7psi$

B. $19psi$

C. $22psi$

D. $34psi$

Start by writing the Bernoulli Equation:

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

Neglect velocity and solve for the pressure difference $\Delta P = P_1 - P_2$. Note $\Delta z = z_2 - z_1 = 30ft$ which is a positive value since the exit is higher than the entrance.

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

The main effort of this problem is determining the losses which must include both major and minor losses (i.e. fitting losses). This requires an additional term beyond the typical application of the Darcy Equation, as can be found by looking up Fittings Losses in the reference handbook:

$$h_f = h_{f,major} + h_{f,minor} = \frac{fLv^2}{2gD} + K\frac{v^2}{2g}$$

Start with the major losses, using the Steel Pipe Friction Tables to find the velocity and actual diameter for a volume flow rate of $200gpm$ in a nominal $4inch$ pipe. Use the Properties of Water table to find the kinematic viscosity at 90°F:

$$Re = \frac{vD}{\nu} = \frac{\left(5.04\frac{ft}{s}\right)(.3355ft)}{.826 \times 10^{-5}\frac{ft^2}{s}} = 205000 \approx 2 \times 10^5$$

Find the relative roughness:

$$\frac{\epsilon}{D} = \frac{.0002ft}{.3355ft} \approx .0006$$

Find the friction factor using the Moody Diagram:

$$f = f\left(Re, \frac{\epsilon}{D}\right) \approx .019$$

Calculate the major losses:

$$h_{f,major} = \frac{fLv^2}{2gD} = \frac{(.019)\,(500ft)\left(5.04\frac{ft}{s}\right)^2}{2\,(.3355ft)\left(32.2\frac{ft}{s^2}\right)} = 11.2ft$$

For the minor losses, look up the K-factors for Flanged Welded Pipe Fittings and take the sum accounting for the quantities. Consider making a table to organize your work:

Flanged Welded Fitting	K-Factor	Total
(4) 90°elbow	.31	1.24
(2) 90° long radius elbow	.22	.44
(2) gate valve	.16	.32
(1) globe valve	6.5	6.5

Taking the overall sum, $K_{total} = 8.5$
Calculate the minor losses:

$$h_{f,minor} = K\frac{v^2}{2g} = 8.5\frac{\left(5.04\frac{ft}{s}\right)^2}{2\left(32.2\frac{ft}{s^2}\right)} = 3.4ft$$

Calculate the total losses:

$$h_f = h_{f,major} + h_{f,minor} = 11.2ft + 3.4ft = 14.6ft$$

Finally, calculate the pressure difference:

$$\frac{P_1 - P_2}{\gamma} = (z_2 - z_1) + h_f = 30ft + 14.6ft = 44.6ft$$

Use the rule of thumb conversion factor for water $2.31\frac{ft}{psi}$ for convenience converting between pressure units and feet of head. Since the value being calculated is a pressure *difference*, it is not appropriate to write psia or psig, but only psi.

$$P_1 - P_2 = \frac{44.6ft}{2.31\frac{ft}{psi}} = 19.3psi$$

Answer B