Insert after Table 2.2 (Minor Friction Loss Coefficients) and before Pump Application and Analysis

Example 2.81

Determine minor friction head losses in equivalent length through the 24 in dia. iron pipe system shown in Figure 2.81 if the flow rate from reservoir A to B is 10 cfs. The pipeline contains one swing check valve (open), one gate valve, one tee, three 90° elbows, and two 45° elbows.

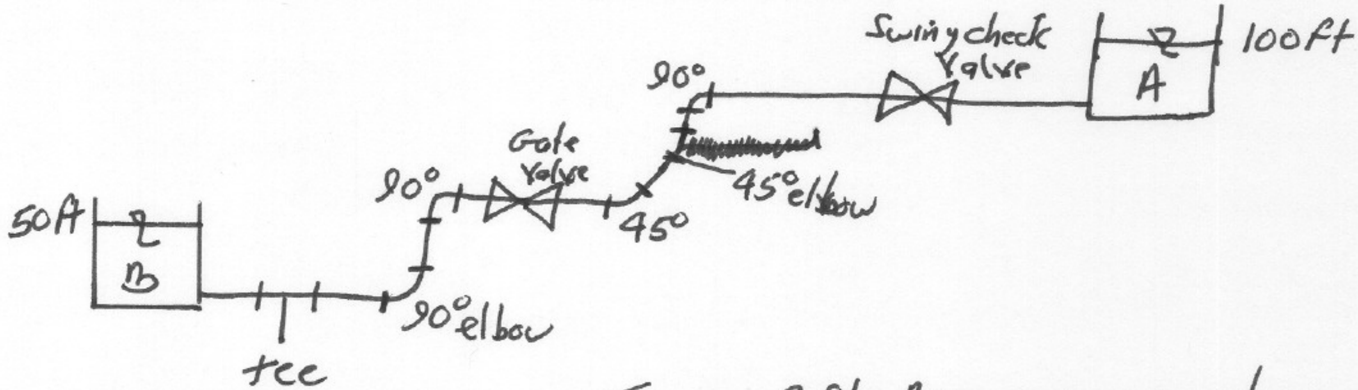


Figure 2.81. Reservoir and pipeline system.

Solution

Minor head losses in a pipe system are computed as:

$$h_L = K\left(\frac{V^2}{2g}\right)$$

Calculate velocity (V) through a 24 in dia. pipe with $Q = 10\frac{ft^3}{sec}$.

$$Q = VA$$

$$V = Q/A = \left(10\frac{ft^3}{sec}\right) \Big/ \pi\left(\left(\frac{24in}{2}\right)\left(\frac{1ft}{12in}\right)\right)^2 = \frac{10}{\pi} = 3.2\frac{ft}{sec}$$

Table ~~2.~~ 2.2 summarizes loss coefficient (K) and friction losses.

K, swing check valve = 2.5 K, 90° elbow = 0.9

K, gate valve = 0.2 K, 45° elbow = 0.4

K, tee = 1.8

$$h_l = K(V^2)$$

$$h_L = 8(0.16) = \boxed{1.3\ ft}$$

Minor pipe losses can also be estimated using the equivalent pipe method. Table ~~2.7~~ 2.91 estimates typical equivalent lengths for steel pipe.

Table 2.91. Typical equivalent length, steel pipe

Fitting	1 in	2 in	4 in
	equivalent length (ft		
Globe valve	29	54	110
angle valve	17	18	18
swing check valve	11	19	38
gate valve	0.8	1.5	2.5
90° pipe elbow	5.2	8.5	13.0
45° pipe elbow	1.3	2.7	5.5
tee	3.2	7.7	17.0

Example 2.~~1~~82

3/8

Determine the total equivalent length of the 2 in steel pipe system shown in Figure 2.82 if the flow rate ~~from~~ from Tank A to B is 0.2 cfs.

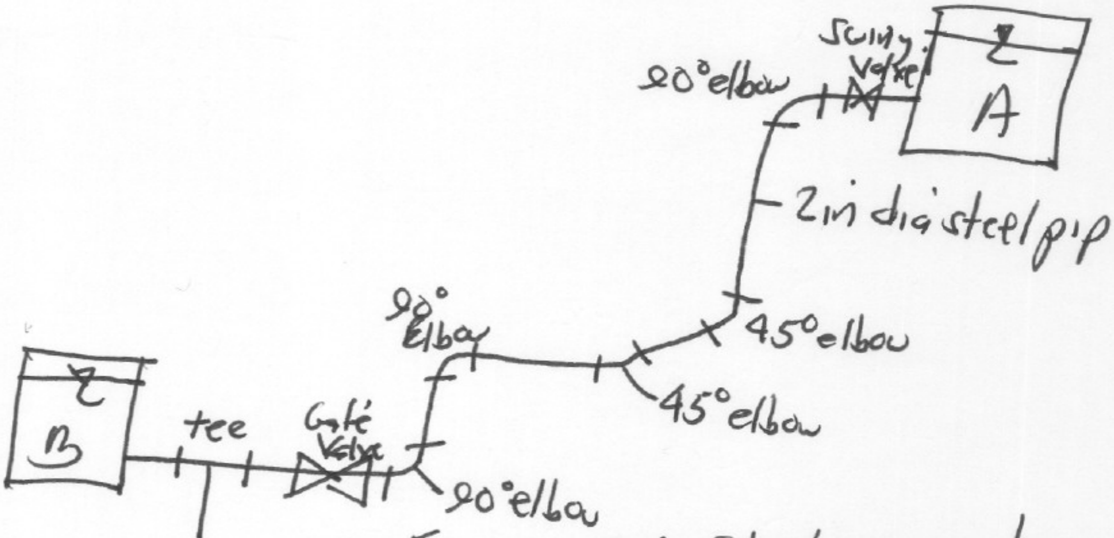


Figure 2.82 Steel pipe system.

From Table 2.91, the ~~total~~ equivalent lengths are:

1-Gate valve,	1 x 1.5	= 1.5
1-Swing valve,	1 x 19	= 19
1-tee,	1 x 7.7	= 7.7
2-45° elbow,	2 x 2.7	= 5.4
3-90° elbow,	3 x 8.5	= 25.5

Total L_{eq} = 59.1 ft

Insert in section on pumps, after Figure 2.9, Total Dynamic Head schematic.

Power (W_s) supplied by a pump is derived by a variation of the energy equation where:

$$\frac{-W_s}{\gamma Q} = \left(\frac{V_2^2 - V_1^2}{2g}\right) + \left(\frac{P_2 - P_1}{\gamma}\right) + \left(z_2 - z_1\right) + h_L$$

⇐ Insert A

Example 2.95

What size (horsepower) pump is needed to increase water pressure by 30 psi in a 6 in dia level pipe where the flow rate is 1.0 ft³/sec?

Solution

The pump power equation is:

$$\frac{-W_s}{\gamma Q} = \left(\frac{V_2^2 - V_1^2}{2g}\right) - \frac{(P_2 - P_1)}{\gamma} + \left(z_2 - z_1\right)$$

The velocity terms subtracted from each other $= 0$.

$z_2 - z_1 = 0$

$$\frac{-W_s}{\left(62.4 \frac{lb}{ft^3}\right)\left(1.0 \frac{ft^3}{sec}\right)} = \frac{\left(30 \frac{lb}{in^2} - 0\right)\left(\frac{12\,in}{1\,ft}\right)^2}{62.4 \frac{lb}{ft^3}}$$

$$\frac{-W_s}{\left(62.4 \frac{lb}{ft^3}\right)} = 69\,ft = \left(4306 \frac{ft\text{-}lb}{sec}\right) \frac{1}{\left(550 \frac{ft\text{-}lb}{sec}\right)}$$

$-W_s = 7.8$ Hp (The pump power needed is 7.8 Horsepower)

Inset A before Example 2.95

~~Pump ... defined by pump head, pump power,~~

Brake power, $\dot{W}_\eta = \dfrac{\dot{W}}{\eta}$ where η = pump efficiency

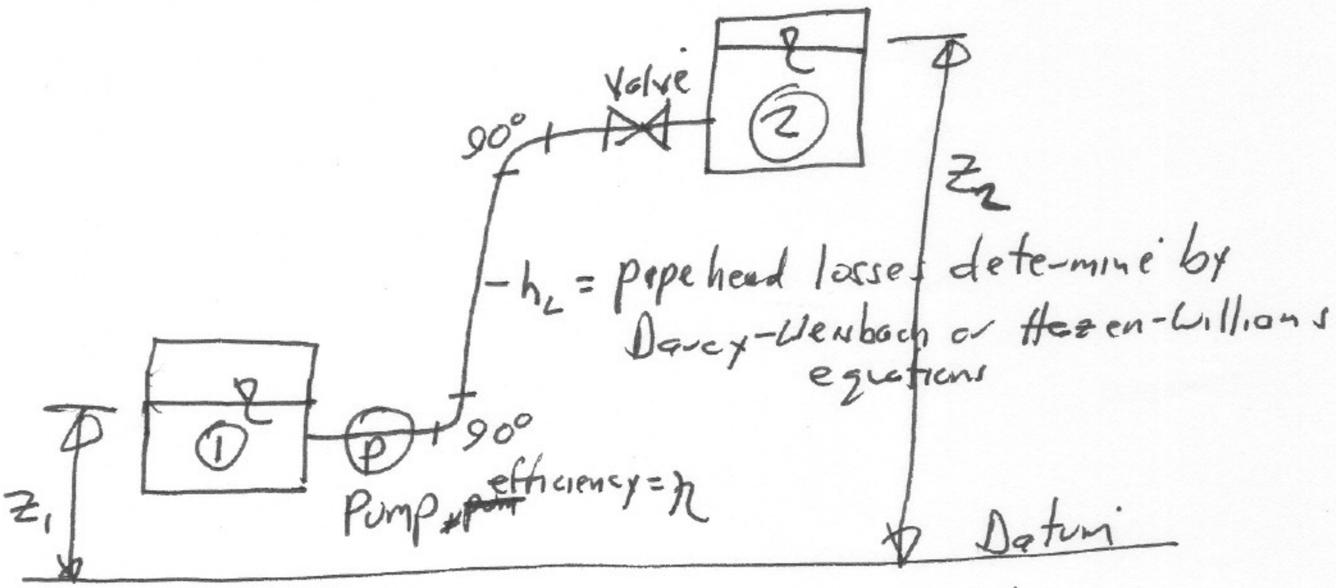


Figure 2.?. Pump and pipe losses Schematic

~~Reference to figure 2.?, pump~~

~~Pump Head, $h_p = Z_2 - Z_1 + h_L = Z_2 - Z_1 + h_L$ (Darcy-Weisbach or Hazen-Williams) $+ K\frac{V^2}{2g}$ (2-90° bends and one valve)~~

~~Pump Power, $\dot{W} = \gamma Q h_L$~~

Example 2.26

5/8

What capacity pump is necessary to convey a flow rate of 20 ft^3/sec through 2000 ft a 24 in ductile iron pipe from reservoirs 1 to 2 as shown in Figure 2.83. The water surface elevations of reservoirs 1 and 2 are 100 ft and 200 ft above mean sea level, respectively.

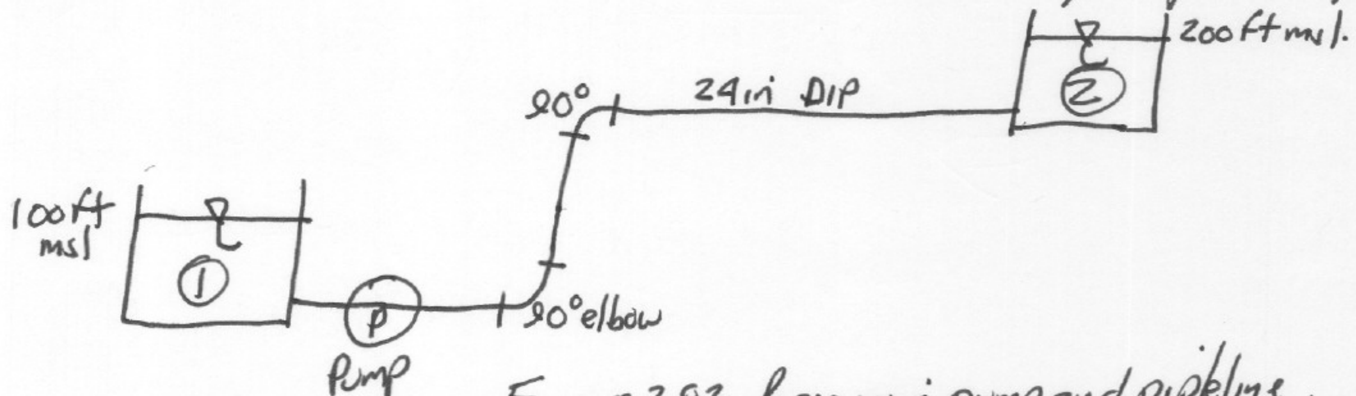


Figure 2.83. Reservoir pump and pipeline schematic.

Solution

Use the pump energy equation:

$$\frac{-W_s}{\gamma Q} = \left[\frac{V_2^2 - V_1^2}{2g}\right] + \left[\frac{p_2 - p_1}{\gamma}\right] + (z_2 - z_1) + h_L$$

The water surface in both reservoirs is still $(V = 0)$ and open to the atmosphere, therefore the velocity and pressure are assumed to be zero.

$V_1 = V_2 = 0$ and

$p_1 = p_2 = 0$

Using the Darcy Weisbach equation to estimate pipe friction and minor head losses ~~equation~~, for the two 90° bends,

$$h_L = \left(K_{90°} + K_{90°} + \frac{fL}{D}\right)\frac{V^2}{2g}$$

The energy equation becomes,

$$\frac{-W_s}{\gamma Q} = 0 + 0 + (z_2 - z_1) + \left(K_{90°} + K_{90°} + \frac{fL}{D}\right)\frac{V^2}{2g}$$

z... – l... ft

Use the Darcy-Weisbach equation to estimate friction loss (f) in the pipe. The pipe velocity is:

$$V = \frac{Q}{A} = 20\,ft^3/sec \Big/ \pi\left[\left(\frac{24\,in}{2}\right)\left(\frac{1\,ft}{12\,in}\right)\right]^2$$

$$V = 20/\pi = 6.4\ ft/sec$$

Compute Reynolds number.

$$R_e = \frac{V D}{\nu} = \frac{\left(6.4\frac{ft}{sec}\right)\left(24\,in\right)\left(\frac{1\,ft}{12\,in}\right)}{\left(10^{-5}\right)}$$

$$R_e = \cancel{12.8}\ 1.3 \times 10^{6}$$

Find e/D, $e = 0.00015\,ft$ (iron pipe, from Moody Diagram, Figure 2.?)

$$D = 24\,in = 2\,ft$$

$$e/D = 0.00015\,ft / 2\,ft = 0.000075$$

Use the Moody Diagram in Figure 2.? to estimate f.

For $R_e = \cancel{12.8}\ 1.3 \times 10^{6}$ and $e/D = 0.000075$,

then $f = 0.013$

Compute pump power needed.

$$\frac{W_s}{\left(62.4\frac{lb}{ft^3}\right)\left(200\frac{ft^3}{sec}\right)} = (200ft - 100ft) + \left(0.9 + 0.9 + \frac{(0.013)(2000ft)}{(24^{in}/12)}\right)\frac{\left(6.4\frac{ft}{sec}\right)^2}{2(32.2)}$$

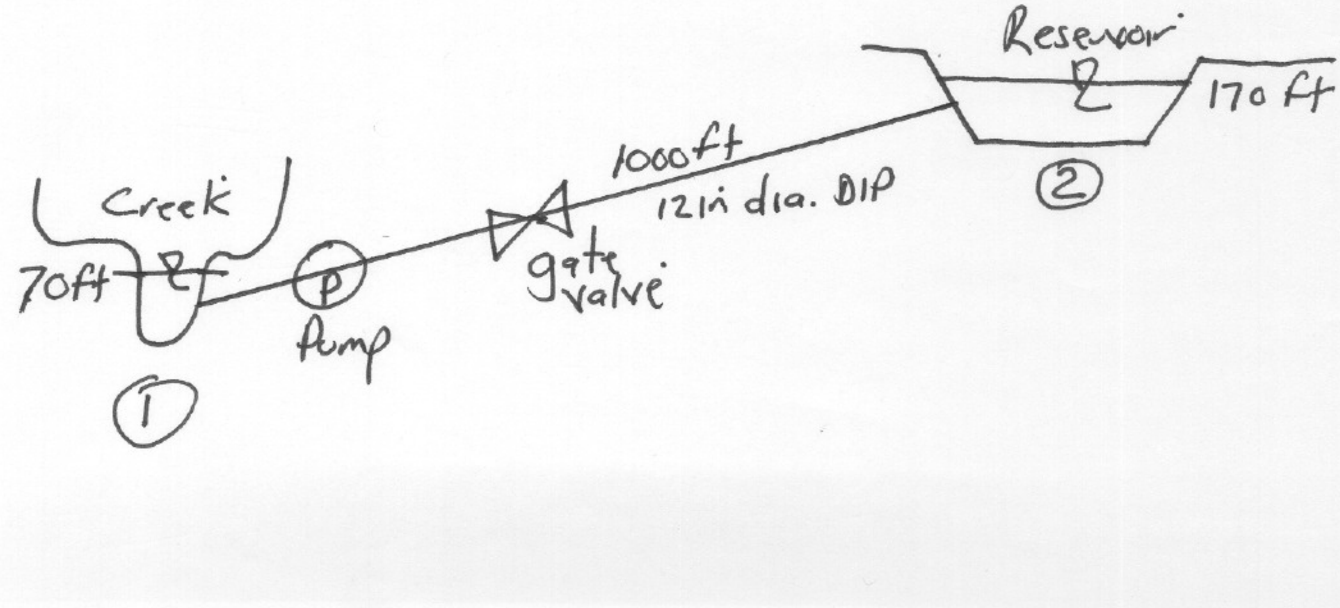
$$\frac{W_s}{1248\frac{lb}{sec}} = 100ft + (14.8)(0.64)$$

$$W_s = \left(136{,}621\frac{ft\text{-}lb}{sec}\right)\left(\frac{1\ Hp}{550\frac{ft\cdot lb}{sec}}\right)$$

$$W_s = 248\ Hp \text{ pump needed}$$

Example 2.97

Water is pumped from a creek at elevation 70ft through a 1000 ft long, 12 in dia. ductile iron pipe to a reservoir at elevation 170ft. The flow rate is 3 ft^3/sec and the pipe contains an open gate valve as depicted in Figure 2.84. Determine the pump head, pump power, and brake power assuming the pump efficiency is 0.80. Determine head loss through the pipe using Hazen-Williams formula.



Solution

Determine the flow rate, pipe area, and velocity.

$$Q = 3\ \frac{ft^3}{sec} \qquad A = \pi r^2 = \pi\left[\left(\frac{12}{2}\right)\left(\frac{1}{12}\right)\right]^2 = 0.78\ ft^3$$

$$V = Q/A = 3/0.78 = 3.8\ ft/sec$$

The head loss through the pipe is computed using Hazen-Williams formula. Assume C = 130, new ductile iron pipe (Table 2.7)

$$h_L = \frac{4.72(L)(V)^{1.85}}{(C)^{1.85}(D)^{4.87}} = \frac{4.72(1000ft)\left(3.8\frac{ft}{sec}\right)^{1.85}}{(130)^{1.85}\ (1ft)^{4.87}}$$

$$h_L = \frac{4720(12)}{8143(1)} = 7\ ft$$

The head loss due to open gate valve:

$$h_L = K\frac{v^2}{2g} = \frac{0.2\,(12.8)^2}{2(32.2)} = 0.5\ ft$$

Total Head Loss = 7 ft + 0.5 ft = 7.5 ft

$$\text{Pump head, } h_p = z_2 - z_1 + h_L = 170ft - 70ft + 7.5ft = \underline{107.5ft}$$

$$\text{Pump power, } \omega = \gamma Q h_p = \left(62.4\frac{lb}{ft^3}\right)\left(3\frac{ft^3}{sec}\right)(107.5ft)$$

$$= \cancel{14,040}\ 20,124\ \frac{ft\text{-}lb}{sec} / 550 = 36.5\ hp$$

$$\text{Brake Power} = \frac{\omega}{\eta} = \frac{36.5\ hp}{0.80} = 45.6\ hp$$