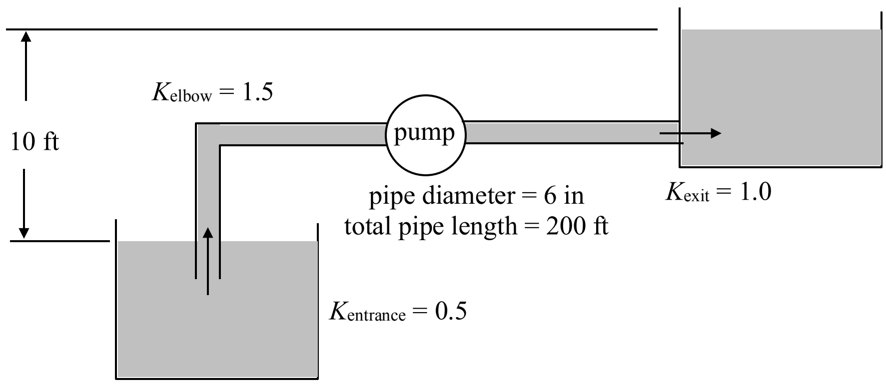
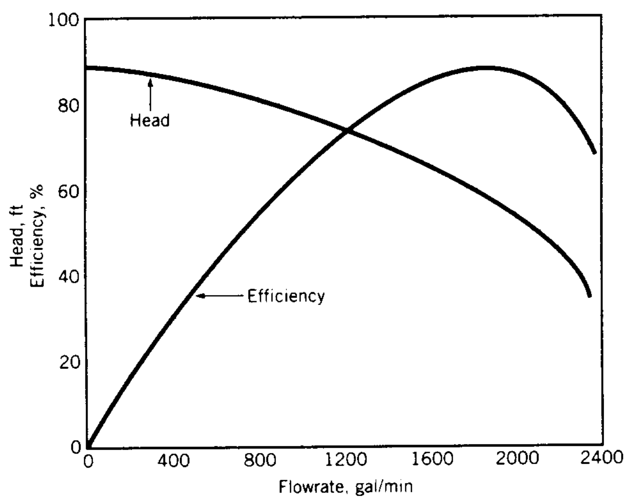
Water is to be pumped from one large open tank to a second large open tank. The pipe diameter throughout is 6 in. and the total length of the pipe between the pipe entrance and exit is 200 ft. Minor loss coefficients for the entrance, exit, and the elbow are shown on the figure and the friction factor can be assumed constant and equal to 0.02. A certain centrifugal pump having the performance characteristics shown is suggested as a good pump for this flow system.

a. With this pump, what would be the flow rate between the tanks?
b. Do you think this pump would be a good choice?

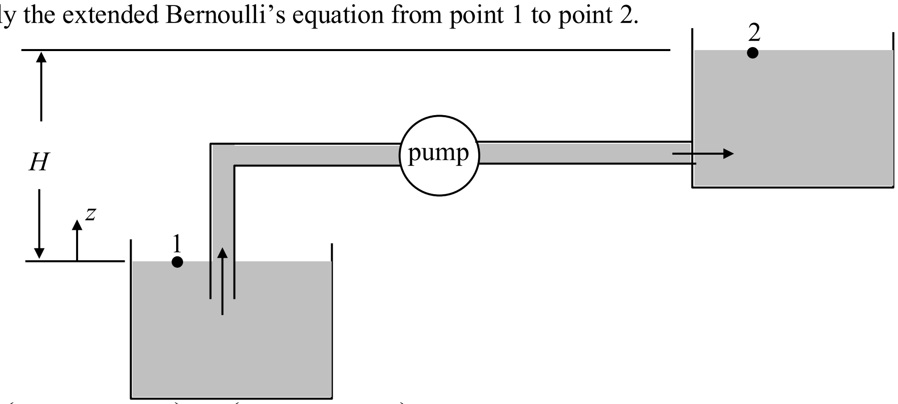




(b)

SOLUTION:

Apply the extended Bernoulli's equation from point 1 to point 2.



$$\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_2=\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_1-H_L+H_S \quad (1)$$

where

$p_2 = p_1 = p_{atm}$ (free surface)

$\bar{V}_2 \approx \bar{V}_1 \approx 0$ (large tanks)

$z_2 - z_1 = H$

$$H_L=\frac{\bar{V}^2}{2g}\left[f\left(\frac{L}{D}\right)+K_{entrance}+K_{exit}+K_{elbow}\right] \quad \text{(where } \bar{V} \text{ is the mean velocity in the pipe)} \quad (2)$$

Note that the mean pipe velocity can be expressed in terms of the volumetric flow rate.

$$\bar{V}=\frac{Q}{\pi D^2/4}$$

Substitute and simplify.

$$H_S=H+\frac{8Q^2}{\pi^2 g D^4}\left[f\left(\frac{L}{D}\right)+K_{entrance}+K_{exit}+K_{elbow}\right] \quad (3)$$

For the given problem:

H	=	10 ft	
g	=	32.2 ft/s^2	
f	=	0.02	
D	=	6 in = 0.5 ft	
L	=	200 ft	(Note: $K_{major} = f(L/D) = 8.0$)
$K_{entrance}$	=	0.5	
K_{exit}	=	1.0	
K_{elbow}	=	1.5	

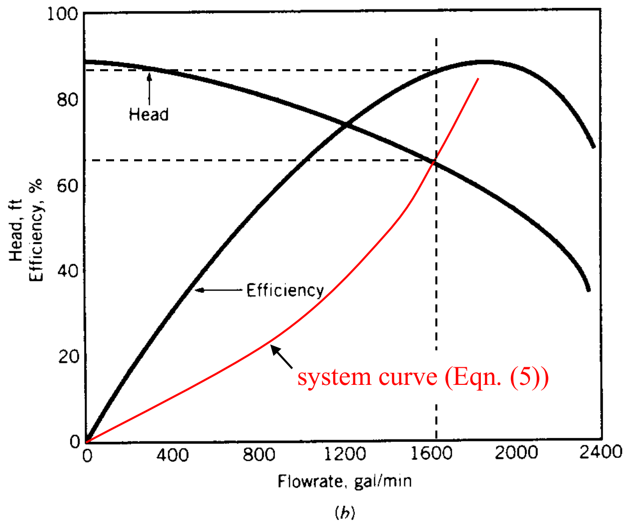
⇒ $H_S = (10 + 4.43Q^2)$ ft   Note that $[Q] = \text{ft}^3/\text{s}$. (4)

This is the head that must be added to the fluid by the pump in order to move the fluid at the volumetric flow rate Q.

With $[Q]$ = gpm, Eqn. (4) becomes:

$\boxed{H_S = (10 + 2.25*10^{-5}Q^2)\text{ ft}}$ Note that $[Q]$ = gpm. (5)

Plot Eqn. (5) on the pump performance curve to determine the operating point.



From the figure we observe that the operating point occurs at:

$\boxed{Q \approx 1600 \text{ gpm}}$

corresponding to a head rise and efficiency of

$H \approx 67$ ft

$\eta \approx 84\%$

The operating efficiency is close to the optimal efficiency of 86% so this is a good pump to use.

The power required to operate this pump is,

$$\dot{W} = \frac{\rho Q g H}{\eta} = \frac{\left(62.4\ \frac{\text{lb}_\text{f}}{\text{ft}^3}\right)\left(1600\ \frac{\text{gal}}{\text{min}}\right)\left(\frac{\text{min}}{60\text{ s}}\right)\left(\frac{\text{ft}^3}{7.48\text{ gal}}\right)\left(66.5\text{ ft}\right)\left(\frac{\text{hp}}{550\ \text{ft.lb}_\text{f}/\text{s}}\right)}{0.84}$$

$$\boxed{\dot{W} = 32.0\text{ hp}}$$