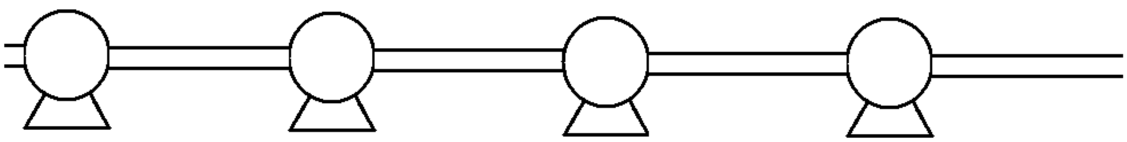
TOPIC

Fluids – Section X – Question 8

QUESTION

A 1.2 m diameter pipeline is used to transport 1.3 m^3/s (940,000 bbl/day) of crude oil over a distance of 1200 km. Because the pressures generated would be too high to do this with a single pump, a series of pumping stations are used as shown in the drawing below. Each pumping station is designed to pump the liquid from 200 kPa at the pump inlet to 1300 kPa at the pump exit. The pipe is smooth and may be assumed to be straight with no elevation gain or loss. Pumps operate at 80 % efficiency. The density and viscosity of the crude oil are 850 kg/m^3 and 0.1 kg/m-s, respectively.



The number of pumping stations required is closest to

(A) 3
(B) 14
(C) 23
(D) 33

HINTS

- The pressure drop in each segment is 1100 kPa
- The number of piping stations is equal to the total length divided by the length of pipe between stations.
- The pressure drop between stations can be related to the length between stations.
- Remember the friction factor.

SOLUTION

Consider the pressure drop in a single segment. The pressure drop in horizontal straight pipe is given by

$$\Delta P = \rho g h_f \quad (1)$$

where h_f is the head loss. The head loss for flow in pipe is given by the Darcy-Weisbach equation

$$h_f = f \frac{L}{D} \frac{v^2}{2g} \quad (2)$$

where

f is the Moody friction factor,
v is the velocity of the fluid in the pipe,
L is the length of the pipe, and
D is the diameter of the pipe.

Substituting the Equation (2) into the Equation (1) and rearranging yields

$$L = \frac{2D\Delta P}{\rho f v^2} \tag{3}$$

The friction factor can be found from the Moody diagram knowing the Reynolds number. The Reynolds number Re is

$$Re = \frac{\rho v D}{\mu} \tag{4}$$

where μ is viscosity.

The velocity is obtained from

$$v = \frac{Q}{(\pi D^2/4)}$$

$$= \frac{1.3m^3/\text{s}}{\frac{\pi(1.2m)^2}{4}}$$

$$\rightleftarrows\rightleftarrows\rightleftarrows\rightleftarrows\rightleftarrows\rightleftarrows = 1.15\text{m/s} \tag{5}$$

The Reynolds number becomes

$$Re = \frac{(850\text{kg/m}^3)(1.15\text{m/s})(1.2m)}{0.1\text{kg/m} \cdot s}$$

$$= 11{,}730 \tag{6}$$

From the Moody diagram for smooth pipe, f is found to be 0.03. Thus, using equation (3)

$$L = \frac{2(1.2m)(1300 - 200)\text{kPa}}{(850\text{kg/m}^3)(0.03)(1.15\text{m/s})^2} \frac{1000\text{kg/m} \cdot s^2}{\text{kPa}}$$

$$= 90{,}025m$$

$$= 90\text{km} \tag{7}$$

The number of pumping stations, n, is then the total distance divided by the length of each segment

$$n = \frac{1200\text{km}}{90\text{km}}$$

$$= 13.3$$

$$\approx 14 \tag{8}$$

ANSWER

(B)

CONTRIBUTOR

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