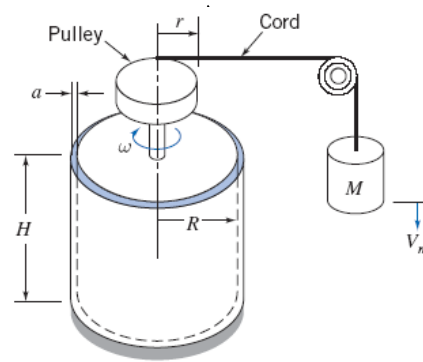


**2.58** A concentric cylinder viscometer may be formed by rotating the inner member of a pair of closely fitting cylinders. The annular gap is small so that a linear velocity profile will exist in the liquid sample. Consider a viscometer with an inner cylinder of 4 in. diameter and 8 in. height, and a clearance gap width of 0.001 in., filled with castor oil at 90°F. Determine the torque required to turn the inner cylinder at 400 rpm.



Solution:

The required torque must balance the resisting torque of the shear force.

The shear force is given by  $F = \tau A$  where  $A = 2\pi R h$

For a Newtonian fluid  $\tau = \mu \frac{du}{dy}$

For small gap (linear profile)  $\tau = \mu \frac{V}{d}$

where  $V =$  tangential velocity of inner cylinder  $= R\omega$

Hence 
$$F = \tau A = \mu \frac{R\omega}{d} 2\pi R h = \frac{2\pi \mu R^2 \omega h}{d}$$

and the torque  $T = RF = \frac{2\pi \mu R^3 \omega h}{d}$

From Fig A.2, for castor oil at 90°F (32°C),  $\mu = 3.80 \times 10^{-1} \text{ N}\cdot\text{s}/\text{m}^2$

Substituting numerical values.

$$T = \frac{2\pi \mu R^3 \omega h}{d} = 2\pi \times 3.80 \times 10^{-1} \frac{\text{N}\cdot\text{s}}{\text{m}^2} \times 2.09 \times 10^{-2} \frac{\text{lb}\cdot\text{s}}{\text{ft}^2 \cdot \text{N}\cdot\text{s}} \times (2.0)^3 \text{ in}^3 \times \frac{400 \text{ rev}}{\text{min}} \times 8 \text{ in} \times \frac{1}{10^{-3} \text{ in}}$$

$$\times 2\pi \frac{\text{rad}}{\text{rev}} \times \frac{\text{min}}{60 \text{ s}} \times \frac{\text{ft}^3}{1728 \text{ in}^3}$$

$T = 77.4 \text{ ft}\cdot\text{lb}$

Torque