

36.18 100,000 $\frac{lbm}{hr}$ of steam at 5psig with quality $\chi = 0.9$ flows through a pipe with an inside diameter of 20in. What is the velocity?

- A. 230 $\frac{ft}{s}$
- B. 255 $\frac{ft}{s}$
- C. 850 $\frac{ft}{s}$
- D. 940 $\frac{ft}{s}$

Since the steam is a saturated mixture, use the quality to determine the specific volume at 5psig. Use the steam table by searching **Properties of Saturated Water and Steam** by pressure. 5psig \approx 20psia. Collect the values for specific volume of a liquid, v_f , and specific volume change during phase change, v_{fg} .

$$v_f = 0.0168 \frac{ft^3}{lb}$$

$$v_{fg} = 20.09 \frac{ft^3}{lb}$$

Use the equation for **specific volume of a two-phase system**.

$$v = v_f + \chi v_{fg} = 0.0168 \frac{ft^3}{lb} + (0.9) \left(20.09 \frac{ft^3}{lb} \right) = 18.1 \frac{ft^3}{lb}$$

Next find the area of a pipe with an inside diameter of 20in in ft^2 .

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \left(\frac{20in}{\left(\frac{12in}{1ft} \right)} \right)^2 = 2.182 ft^2$$

Mass flow rate is the product of density and volume flow rate: $\dot{m} = \rho Q$.

Volume flow rate is the product of velocity and area: $Q = VA$.

Combine the above and solve for velocity. Substitute specific volume in the numerator for density in the denominator, since they are inverses. Substitute known values and solve for the velocity, converting units as needed to drive the final answer to $\frac{ft}{s}$.

$$\dot{m} = \rho VA$$

$$V = \frac{\dot{m}}{\rho A} = \frac{\dot{m} v}{A} = \frac{(100,000 \frac{lb}{hr}) \left(\frac{1hr}{3600s} \right) \left(18.1 \frac{ft^3}{lb} \right)}{2.182 ft^2} = 230 \frac{ft}{s}$$

Answer A