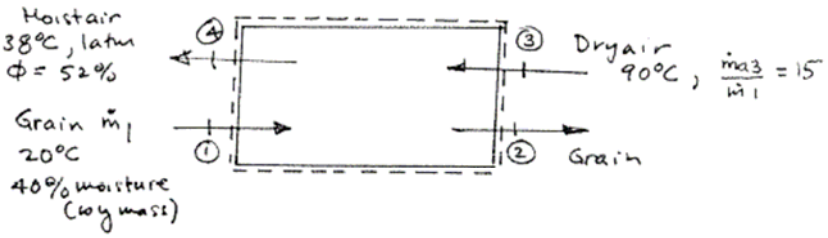
PROBLEM 12.54

KNOWN: Grain containing 40% moisture by mass enters a dryer operating at steady state. Dry air also enters and a moist air stream exits.

FIND: For the grain that exits the dryer, determine the percent moisture by mass.

SCHEMATIC & GIVEN DATA:



ENGINEERING MODEL: (1) The control volume is at steady state. (2) Ideal gas principles apply to the dry air and moist air streams.

ANALYSIS: The percent moisture by mass of the exiting grain is evaluated as

$$(1) \qquad \% = (100)\left(\frac{\dot{m}_{Moisture,2}}{\dot{m}_2}\right) \leftarrow \text{rate moisture exits at 2} \quad \leftarrow \text{total rate grain plus moisture exits at 2}$$

Mass balance on water:

$$\dot{m}_{moisture,1} + 0 = \dot{m}_{moisture,2} + \dot{m}_{v4} \Rightarrow \dot{m}_{moisture,2} = 0.4\dot{m}_1 - \dot{m}_{v4} \quad (2)$$

(moisture in; moisture out; dry air enters at 3)

Mass balance on dry air: $\dot{m}_{a4} = \dot{m}_{a3} = 1.5\,\dot{m}_1$. Additionally $\omega_4 = \dot{m}_{v4}/\dot{m}_{a4}$. So

$\dot{m}_{v4} = \omega_4 \dot{m}_{a4} = \omega_4(1.5\,\dot{m}_1)$. To find ω_4, calculate $P_{v4} = \phi_4 P_{g4}$ or

$P_{v4} = 0.52(0.06632\,bar) = 0.0345\,bar$ and

$$\omega_4 = \frac{.622\,P_{v4}}{P_4 - P_{v4}} = \frac{.622(0.0345)}{1.01325 - 0.0345} = 0.022\ \frac{kg(v)}{kg(a)}$$

Thus

$$\dot{m}_{v4} = (0.022)(1.5)\dot{m}_1 = 0.33\,\dot{m}_1 \quad (3)$$

Also, the total mass flow rates at 1,2 differ by the amount of moisture removed. Thus is

$$\dot{m}_2 = \dot{m}_1 - \dot{m}_{v4} = \dot{m}_1 - 0.33\,\dot{m}_1 = 0.67\,\dot{m}_1 \quad (4)$$

Collecting Eqs. (1), (2), (3), (4)

$$\% = \left(\frac{0.4\,\dot{m}_1 - 0.33\dot{m}_1}{0.67\,\dot{m}_1}\right)(100) = 10.4 \quad \leftarrow$$