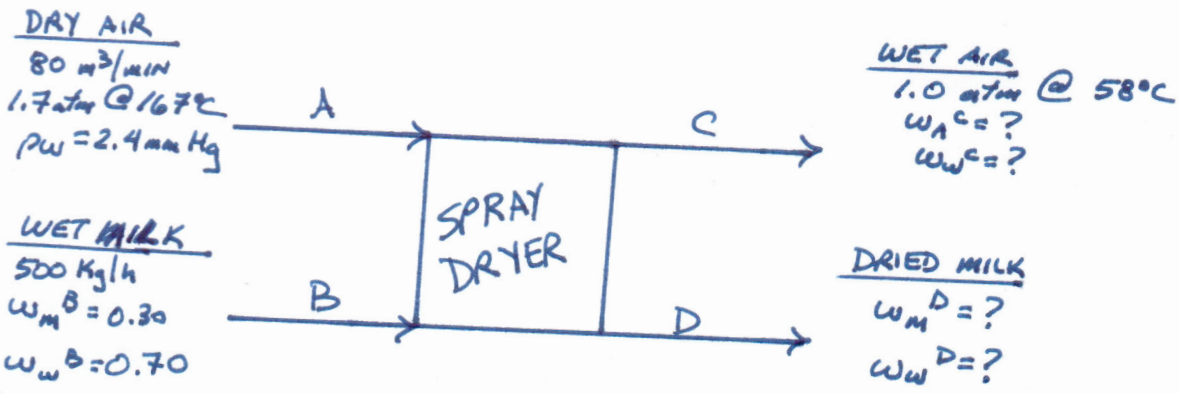
(1)



COMPONENTS	STREAMS A	B	C	D
M = MILK SOLIDS		X		X
W = WATER	X	X	X	X
A = AIR	X		X	

OTHER INFO: 98% OF WATER IN MILK EVAPORATES
2% OF WATER IN MILK REMAINS IN "DRIED MILK"

WATER IN MILK: $\dot{m}_w^B = (0.70)(500) = 350$ Kg/h

WATER IN STREAM B WHICH EVAPORATES = $(0.98)(350) = 343$ Kg/h

WATER IN STREAM B WHICH REMAINS = $(0.02)(350) = 7$ Kg/h $= \dot{m}_w^D$

MILK BALANCE

ACC = IN − OUT + GEN

$0 = (0.30)(350) + \dot{m}_m^D$ $\qquad \dot{m}_m^D = 150$ Kg/h

$\dot{m}^D = \dot{m}_m^D + \dot{m}_w^D = 150 + 7 = 157$ Kg/h

$\omega_w^D = \dfrac{\dot{m}_w^D}{\dot{m}^D} = \dfrac{7}{157} = 0.0446$ (ANSWER TO PART c)

AIR BALANCE

ACC = IN − OUT + GEN

$0 = \dot{m}_A^A - \dot{m}_A^C$

MORE INFORMATION IS KNOWN ABOUT STREAM A:

$T = 440$K

$P_A = P - P_w = (1.7)(760) - 2.4 = 1289.6$ mm Hg

$Q^A = 80$ m³/min

$M_A = 29.0$ g/mol

$P_A^A Q^A = \dot{n}_A^A R T^A$

NOTE: STRICTLY SPEAKING, PARTIAL PRESSURE OF DRY AIR IS LESS THAN PRESSURE OF INLET "AIR".

$(1289.6 \text{ mm Hg})(80 \text{ m}^3/\text{min})(1000 \text{ L/m}^3) = \dot{n}_A^A (62.36 \text{ L mm Hg/mol K})(440 \text{ K})$

$\dot{n}_A^A = 3760$ mol/min

$$\dot{m}_A^A = \dot{n}_A^A \cdot M_A$$

$$= \left(3760 \frac{mol}{min}\right)\left(\frac{29.0\ g}{mol}\right)\left(\frac{60\ min}{h}\right)\left(\frac{Kg}{1000\ g}\right) = \underline{6542.4\ Kg/h}$$

SO RETURNING TO MASS BALANCE:

$$0 = \dot{m}_A^A - \dot{m}_A^C = 6542.4 - \dot{m}_A^C$$

$$\dot{m}_A^C = \underline{6542.4\ Kg/h} \quad \text{(DRY AIR IN STREAM C)}$$

NOTE: WE COULD ALSO DO MOLE BALANCE AND AVOID USING MOLECULAR WEIGH

WATER BALANCE

$$ACC = IN - OUT + GEN$$

$$0 = \dot{m}_W^A + \dot{m}_W^B - \dot{m}_W^C - \dot{m}_W^D$$

RECALL $\dot{m}_W^D = 7\ Kg/h$ (MILK BALANCE ABOVE)

$\dot{m}_W^B = 350\ Kg/h$

CALCULATE $\dot{m}_W^A$ AND THEN USE THIS BALANCE TO FIND $\dot{m}_W^C$.

FOR STREAM A:

$T = 440K$

$P_W = 2.4\ mm\ Hg$

$Q = 80\ m^3/min$

$M_W = 18.0\ g/mol$

$$P_W^A Q^A = \dot{n}_W^A R T^A$$

$$(2.4\ mm\ Hg)(80\ m^3/min)(1000\ L/m^3) = \dot{n}_W^A (6236\ L\ mm\ Hg/mol\ K)(440K)$$

$$\dot{n}_W^A = 7.00\ mol/min$$

$$\dot{m}_W^A = (7.00\ mol/min)(18.0\ g/mol)(60\ min/h)(Kg/1000g) = \underline{7.56\ Kg/}$$

SO, $0 = 7.56 + 350 + \dot{m}_W^C - 7 \Rightarrow \dot{m}_W^C = \underline{350.6\ Kg/h}$

$= 324.6\ mol/min$

IN SUMMARY "WET AIR" CONTAINS

6542.4 Kg/h AIR = 3760 mol/min AIR

350.6 Kg/h WATER = 324.6 mol/min WATER

4085 mol/min (TOTAL)

$$P^c Q^c = \dot{n}^c R T^c$$

$$(760\ mm\ Hg)\, Q^c = \left(4085\ \frac{mol}{min}\right)\left(62.36\ \frac{L\ mm\ Hg}{mol\ K}\right)(331\ K)\left(\frac{m^3}{1000\ L}\right)$$

$$Q^c = \underline{110.9\ m^3/min} \qquad \text{(ANSWER TO PART ii)}$$

RELATIVE HUMIDITY

$$h_r{}^c = \frac{100\, p_w{}^c}{p_w{}^*} = \frac{100\, y_w{}^c P^c}{p_w{}^*}$$

$p_w{}^*(331\ K) = 135.2\ mm\ Hg$ (FROM VAPOR PRESSURE EQN)

$$y_w{}^c = \frac{324.6}{4085} = 0.0796$$

$$h_r{}^c = \frac{(100)(0.0796)(760\ mm\ Hg)}{(135.2\ mm\ Hg)} = \underline{44.7\%}$$

(ANSWER TO PART iii)