

Alumno: _____ Mail: _____



Integración III

Parcial ° 1: Psicrometría.

Tema B

Una corriente de aire a 30 [°C], 1 [atm] cuya humedad relativa es el 50 % ingresa a una torre de enfriamiento. El agua de enfriamiento ingresa a 40 [°C] y su flujo es de 1000 [kg/hr] mientras que el aire sale a 30 [°C]. Calcular:

- La cantidad de aire necesario.
- Cantidad de agua evaporada.
- Si el agua de reposición ingresa a 25 [°C] a qué temperatura saldría el agua de enfriamiento.
- El calor que se puede extraer del proceso.

Datos:

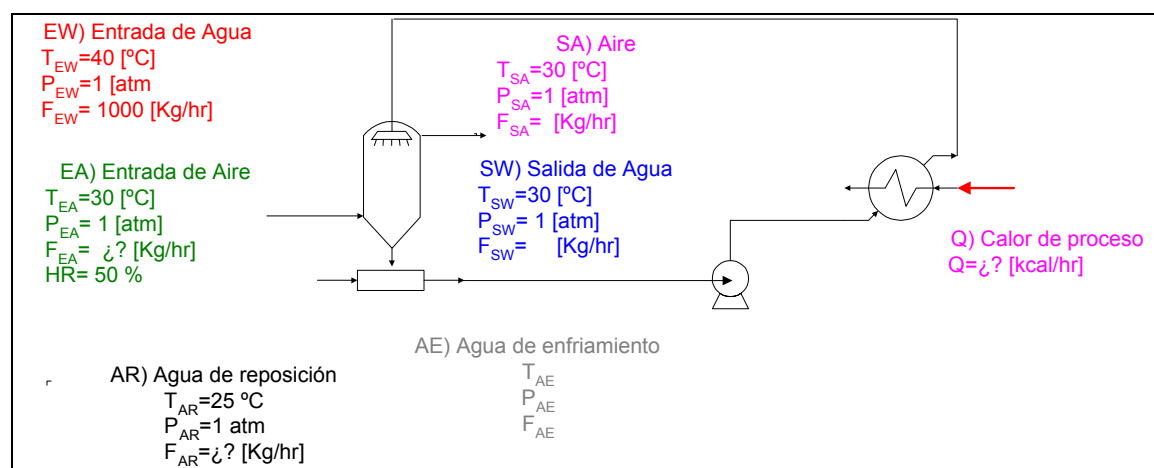
$$\log_{10}(P_s) = 8,07131 - \frac{1730,63}{233,426 + t} \quad \text{con } P_s \text{ en [mmHg] y } t \text{ en [°C]}$$

Entalpía del aire húmedo:

$$\overline{\Delta H} = 0,24 \times t + HA \times (595 + 0,46 \times t) \quad \text{En [kcal/Kg aire seco] y } t \text{ en [°C]}$$

CP del agua líquida:

$$\overline{C_p} = 1 \quad \text{En [kcal/Kg °C]}$$



Solución:

Entrada de aire: EA)

$$F_{EA} = ? \text{ [kg/hr]}$$

$$t_{EA} = 30 \text{ [}^{\circ}\text{C]}$$

$$P_{EA} = 1 \text{ [atm]} = 760 \text{ [mmHg]}$$

$$\log_{10}(P_s^{EA}) = 8,07131 - \frac{1730,63}{233,426 + 30}$$

$$P_s^{EA} = 31,74 \text{ [mmHg]} = 0,041763 \text{ [atm]}$$

$$HR_{EA} = 50 \%$$

$$P_V^{EA} = \frac{P_s^{EA} \times HR_{EA}}{100} = 15,87 \text{ [mmHg]} = 0,02088 \text{ [atm]}$$

$$x_{Agua}^{EA} = \frac{P_V^{EA}}{P_{EA}} = \frac{0,02088}{1} = 0,02088$$

$$x_{Aire}^{EA} = 1 - x_{Agua}^{EA} = 0,97912$$

$$Hm_{EA} = \frac{P_V^{EA}}{P_{EA} - P_V^{EA}} = \frac{0,02088}{1 - 0,02088} = 0,021327 \left[\frac{\text{kmol agua}}{\text{kmol aire seco}} \right]$$

$$HA_{EA} = \frac{PM_{Agua}}{PM_{Aire}} Hm_{EA} = 0,6241 \times 0,021327 = 0,013311 \left[\frac{\text{kg agua}}{\text{kg aire seco}} \right]$$

$$\overline{\Delta H}_{EA} = 0,24 \times 30 + 0,013311 \times (595 + 0,46 \times 30) = 15,304 \left[\frac{\text{kcal}}{\text{kg aire seco}} \right]$$

$$F_{Aireseco}^{EA} = F_{EA} \times (1 - HA_{EA}) = 0,9867 \times F_{EA} \left[\frac{\text{kg Aire seco}}{\text{hr}} \right]$$

$$FE_{EA} = F_{Aireseco}^{EA} \times \overline{\Delta H}_{EA} = 0,9867 \times F_{EA} \left[\frac{\text{kg aire seco}}{\text{hr}} \right] \times 15,304 \left[\frac{\text{kcal}}{\text{kg aire seco}} \right] = 15,10 \times F_{EA} \left[\frac{\text{kcal}}{\text{hr}} \right]$$

Entrada de agua: EW)

$$F_{EW} = 1000 \text{ [kg/hr]}$$

$$t_{EW} = 40 \text{ [}^{\circ}\text{C]}$$

$$\overline{\Delta H}_{EW} = 1 \left[\frac{\text{kcal}}{\text{kg}^{\circ}\text{C}} \right] \times 40 \text{ [}^{\circ}\text{C}] = 40 \left[\frac{\text{kcal}}{\text{kg}} \right]$$

$$FE_{EW} = F_{EW} \times \overline{\Delta H}_{EW} = 1000 \left[\frac{kg \text{ Agua}}{hr} \right] \times 40 \left[\frac{kcal}{kg \text{ Agua}} \right] = 4,000 \times 10^4 \left[\frac{kcal}{hr} \right]$$

Salida de aire: SA)

$$F_{SA} = [kg/hr]$$

$$T_{SA} = 30 [^{\circ}C]$$

$$P_{SA} = 1 [atm] = 760 [mmHg]$$

$$\log_{10}(P_S^{SA}) = 8,07131 - \frac{1730,63}{233,426 + 30}$$

$$P_S^{SA} = 31,74 [mmHg] = 0,04176 [atm]$$

$$HR_{SA} = 100 \%$$

$$P_V^{SA} = \frac{P_S^{SA} \times HR_{SA}}{100} = 31,74 [mmHg] = 0,04176 [atm]$$

$$x_{Agua}^{SA} = \frac{P_V^{EA}}{P_{EA}} = \frac{0,04176}{1} = 0,04176$$

$$x_{Aire}^{SA} = 1 - x_{Agua}^{EA} = 0,9582$$

$$HmA_{SA} = \frac{P_V^{EA}}{P_{EA} - P_V^{EA}} = \frac{0,04176}{1 - 0,04176} = 0,04358 \left[\frac{kmol \text{ agua}}{kmol \text{ aire seco}} \right]$$

$$HA_{SA} = \frac{PM_{Agua}}{PM_{Aire}} HmA_{EA} = 0,6241 \times 0,04358 = 0,02720 \left[\frac{kg \text{ agua}}{kg \text{ aire seco}} \right]$$

$$\overline{\Delta H}_{SA} = 0,24 \times 30 + 0,02720 \times (595 + 0,46 \times 30) = 23,76 \left[\frac{kcal}{kg \text{ aire seco}} \right]$$

$$F_{Aireseco}^{SA} = F_{Aireseco}^{EA} = 0,9867 \times F_{EA} \left[\frac{kg \text{ aire seco}}{hr} \right]$$

$$FE_{SA} = F_{Aireseco}^{SA} \times \overline{\Delta H}_{EA} = 0,9867 \times F_{EA} \left[\frac{kg \text{ aire seco}}{hr} \right] \times 23,76 \left[\frac{kcal}{kg \text{ aire seco}} \right] = 23,44 \times F_{EA} \left[\frac{kcal}{hr} \right]$$

Salida de agua: SW)

$$F_{SW} = F_{EW} - F_{Agua}^{Evap} = ? [kg/hr]$$

$$T_{SW} = 20 [^{\circ}C]$$

$$FE_{SW} = F_{SW} \times \overline{\Delta H}_{SW} = F_{SW} \times 30 \left[\frac{kcal}{hr} \right]$$

$$F_{EA} + F_{EW} = F_{SA} + F_{SW}$$
$$F_{EA} \times (1 - HA_{EA}) = F_{SA} \times F_{SA} (1 - HA_{SA})$$
$$FE_{EA} + FE_{EW} = FE_{SA} + FE_{SW}$$
$$F_{EA} \times (1 - 0,01331) = F_{SA} \times (1 - 0,02720)$$

$$F_{EA} \times (0.9867) = F_{SA} \times (0.9728)$$

$$F_{SA} = \frac{F_{EA} \times (0.9867)}{(0.9728)} = 1.014 \times F_{EA}$$

$$15,10 \times F_{EA} + FE_{EW} = 23,44 \times F_{EA} + F_{SW} \times 30$$
[illegible]

$$F_{SW} = \frac{15,10 \times F_{EA} + FE_{EW} - 23,44 \times F_{EA}}{30} = \frac{FE_{EW} - 8,340 \times F_{EA}}{30}$$

$$F_{EA} + F_{EW} = F_{SA} + F_{SW}$$

$$F_{EA} + F_{EW} = 1.014 \times F_{EA} + \frac{FE_{EW} - 8,340 \times F_{EA}}{30} = 1.014 \times F_{EA} + 1333 - 0,278 \times F_{EA}$$

Reordenando:

$$F_{EA} \times (1 - 1,014 + 0,278) + F_{EW} = 1333$$

$$F_{EA} \times 0,264 + F_{EW} = 1333$$

$$F_{EA} = \frac{1333 - F_{EW}}{0,264} = \frac{1333 - 1000}{0,264} = 1261 \left[\frac{kg}{hr} \right]$$

$$F_{SA} = 1,014 \times F_{EA} = 1,014 \times 1261 = 1279 \left[\frac{kg}{h} \right]$$

$$F_{SW} = F_{EA} + F_{EW} - F_{SA} = 1261 + 1000 - 1279 = 982,0 \left[\frac{kg}{hr} \right]$$

$$F_{Aireseco}^{SA} = F_{EA} \times (1 - HA_{EA}) = 1261 \times (1 - 0,01331) = 1044 \left[\frac{kg}{hr} \right]$$

Agua Evaporada: EV)

$$F_{Agua}^{Evap} = F_{Aireseco}^{SA} \times (HA_{SA} - HA_{EA}) = 1244 \times (0,02720 - 0,01331) = 17,28 \left[\frac{kg}{hr} \right]$$

Pileta:

$$F_{Ar} = F_{Agua}^{Evap} = 17,28 \left[\frac{kg}{hr} \right]$$

$$\overline{\Delta H}_{AR} = 25 \left[\frac{kcal}{hr} \right]$$

$$F_{AE} \times \overline{\Delta H}_{AE} = F_{SW} \times \overline{\Delta H}_{SW} + F_{AR} \times \overline{\Delta H}_{AR}$$

$$\overline{\Delta H}_{AE} = \frac{F_{SW} \times \overline{\Delta H}_{SW} + F_{AR} \times \overline{\Delta H}_{AR}}{F_{AE}} = \frac{982 \times 30 + 17,28 \times 25}{1000} = 29,89 \left[\frac{kcal}{hr} \right]$$

$$\overline{\Delta H}_{AE} = Cp \times t_{AE} =$$

$$t_{AE} = \frac{\overline{\Delta H}_{AE}}{Cp} \frac{29,89 \left[\frac{kcal}{hr} \right]}{29,89 \left[\frac{kcal}{kg^{\circ}C} \right]} = 29,89 \text{ } [^{\circ}C]$$

Balance de energía del proceso:

$$Q = (\overline{\Delta H}_{EW} - \overline{\Delta H}_{AE}) \times F_{EW} = (40 - 29,89) \times 1000 = 1,011 \times 10^4 \left[\frac{kcal}{hr} \right]$$

Respuestas:

a) Se requieren 1261 [kg/hr] de aire.

b) se evaporan 17,28 [kg(hr)] de agua.

c) El agua sale de la pileta a 29,89 [°C]

d) Puede extraerse hasta 1,010x10⁴ [kcal/hr]

EW		
Temperature	40.00	C
Pressure	1.000	atm
Molar Flow	55.51	kgmole/h
Mass Flow	1000	kg/h
Comp Mole Frac (H2O)	1.0000	

EA		
Temperature	30.00	C
Pressure	1.000	atm
Molar Flow	44.01	kgmole/h
Mass Flow	1264	kg/h
Comp Mole Frac (H2O)	0.0210	
Comp Mole Frac (Air)	0.9790	

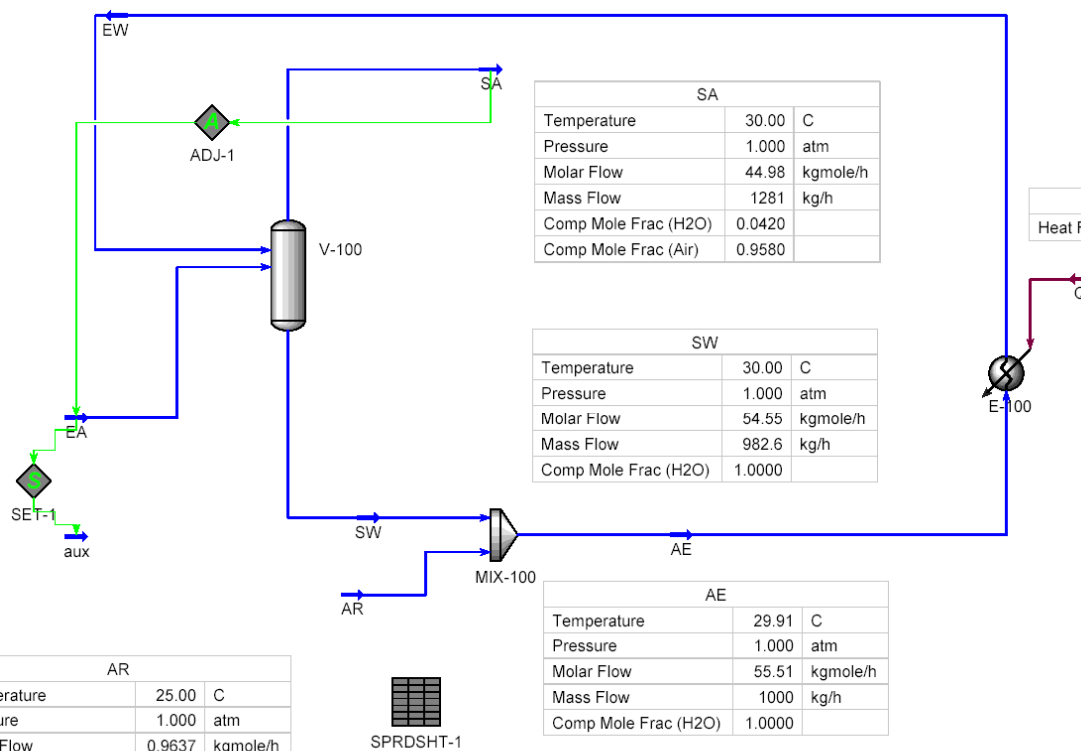
AR		
Temperature	25.00	C
Pressure	1.000	atm
Molar Flow	0.9637	kgmole/h
Mass Flow	17.36	kg/h
Comp Mole Frac (H2O)	1.0000	

SA		
Temperature	30.00	C
Pressure	1.000	atm
Molar Flow	44.98	kgmole/h
Mass Flow	1281	kg/h
Comp Mole Frac (H2O)	0.0420	
Comp Mole Frac (Air)	0.9580	

SW		
Temperature	30.00	C
Pressure	1.000	atm
Molar Flow	54.55	kgmole/h
Mass Flow	982.6	kg/h
Comp Mole Frac (H2O)	1.0000	

AE		
Temperature	29.91	C
Pressure	1.000	atm
Molar Flow	55.51	kgmole/h
Mass Flow	1000	kg/h
Comp Mole Frac (H2O)	1.0000	

Q		
Heat Flow	1.019e+004	kcal/h



Hysys

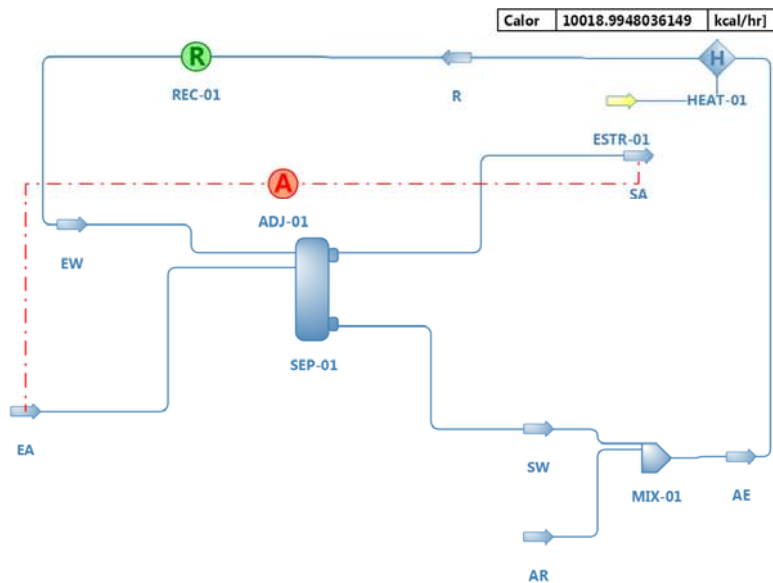
Entrada de agua			
EW	Temperature	40	C
EW	Pressure	1	atm
EW	Mass Flow	1000	kg/h
EW	Molar Flow	55.5081	kmol/h
EW	Molar Fraction (Mixture) / Water	0.99999	

Entrada de aire			
EA	Temperature	30	C
EA	Pressure	1	atm
EA	Mass Flow	1246.41	kg/h
EA	Molar Flow	43.3829	kmol/h
EA	Molar Fraction (Mixture) / Water	0.0209858	
EA	Molar Fraction (Mixture) / Air	0.979014	



Salida de agua			
SW	Temperature	30	C
SW	Pressure	1	atm
SW	Mass Flow	982.88	kg/h
SW	Molar Flow	54.5578	kmol/h
SW	Molar Fraction (Mixture) / Water	0.99999	
SW	Molar Fraction (Mixture) / Air	1.02766E-05	

Agua de reposición			
AR	Temperature	25	C
AR	Pressure	1	atm
AR	Mass Flow	17.1197	kg/h
AR	Molar Flow	0.95029	kmol/h
AR	Molar Fraction (Mixture) / Water	1	



Salida de aire			
SA	Temperature	30	C
SA	Pressure	1	atm
SA	Mass Flow	1263.52	kg/h
SA	Molar Flow	44.3332	kmol/h
SA	Molar Fraction (Mixture) / Water	0.0419711	
SA	Molar Fraction (Mixture) / Air	0.958029	

Agua de enfriamiento			
AE	Temperature	29.9145	C
AE	Pressure	1	atm
AE	Mass Flow	1000	kg/h
AE	Molar Flow	55.5081	kmol/h
AE	Molar Fraction (Mixture) / Water	0.99999	

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