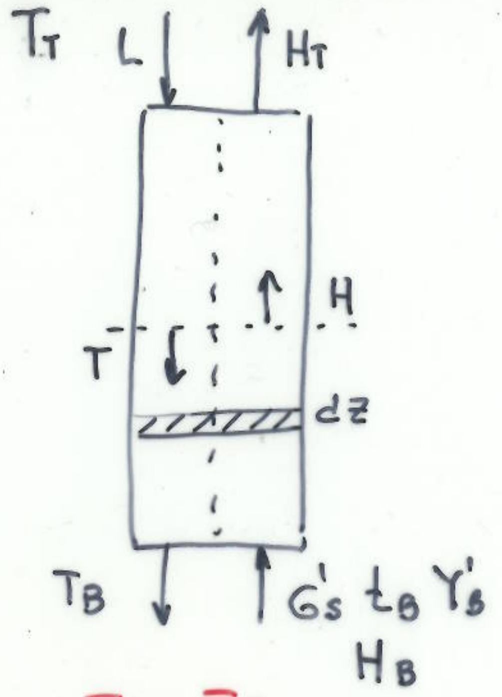
Enfriamiento de Agua

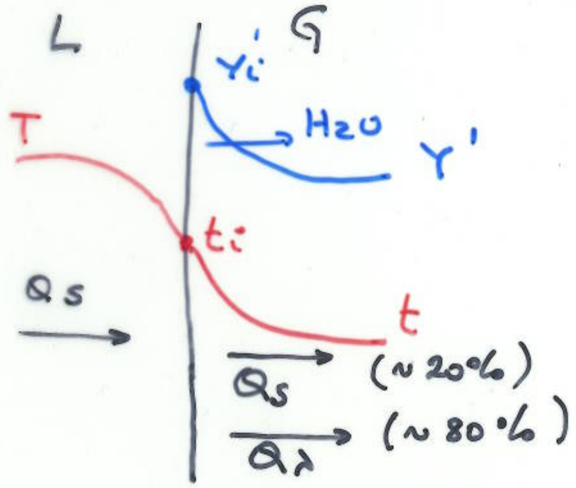


$\Delta T = T_T - T_B$

$\Delta t_w = T_B - t_w$
(aproximación a bulbo húmedo)
$\cong 2{,}5°C$ a $5°C$

$T_B < T_T$
$H_T > H_B$

Parte superior de la torre



Hipótesis :

$L = cte$
(ΔL 1 al 3%)

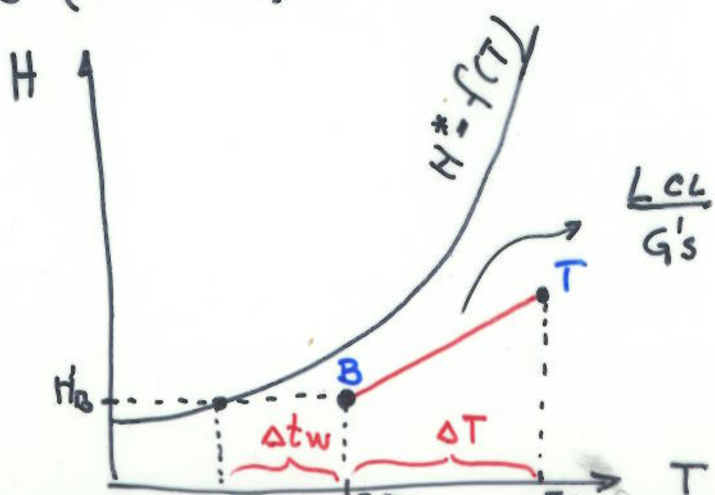
$\lambda, c_s, c_L \neq f(t)$

$Le = \dfrac{h_G}{k_y c_s} = 1$

$t_{ref} = 0°C$

Balance de energía:

$$G'_s \, (H - H_B) = L \, c_L \, (T - T_B)$$



En un dZ :

$$dQ = L c_L \, dT = G'_s \, dH =$$

$$= \left[\underbrace{h_G \, a (t_i - t) \, dV}_{dQ_s} + \underbrace{k_y \, a \, \lambda \, (Y'_i - Y') \, dV}_{dQ_\lambda} \right]_{\text{en el gas}}$$

con $Le = 1$

$$h_G = k_y \, c_s$$
$$\lambda \approx \lambda_0 \neq f(t)$$
$$c_s \neq f(t)$$

$$L c_L \, dT_L = G'_s \, dH = k_y \, a \, dV \left[c_s (t_i - t) + \lambda (Y'_i - Y') \right]$$
$$= k_y \, a \, dV \, (H_i - H)$$

o sea:

$$\frac{k_y a}{L} \int_0^V dV = \int_{T_B}^{T_T} \frac{c_L \, dT}{H_i - H} = C = \frac{k_y a}{L} V = \frac{k_y a \, S_0 Z}{L}$$

C → característica requerida.

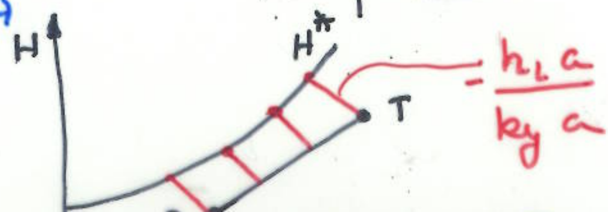
$$\frac{k_y a}{G'_s} \int_0^V dV = \int_{H_B}^{H_T} \frac{dH}{H_i - H} = \frac{k_y a V}{G'_s} = \frac{k_y a \, S_0 Z}{G'_s}$$

$$Z = \frac{G'_s}{k_y a \, S_0} \int_{H_B}^{H_T} \frac{dH}{H_i - H} = H_{TG} \, N_{TG}$$

H_i ?

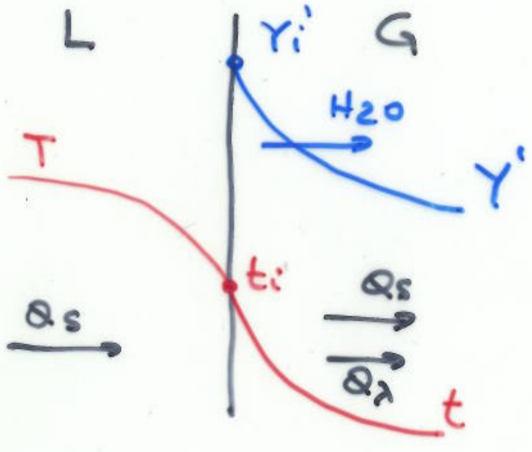
$$\boxed{L c_L \, dT = h_L a \, (T - t_i) \, dV} \text{ en } L$$
$$\boxed{= k_y a \, (H_i - H) \, dV} \text{ en } G$$

$$\boxed{\frac{H_i - H}{t_i - T} = - \frac{h_L a}{k_y a}}$$

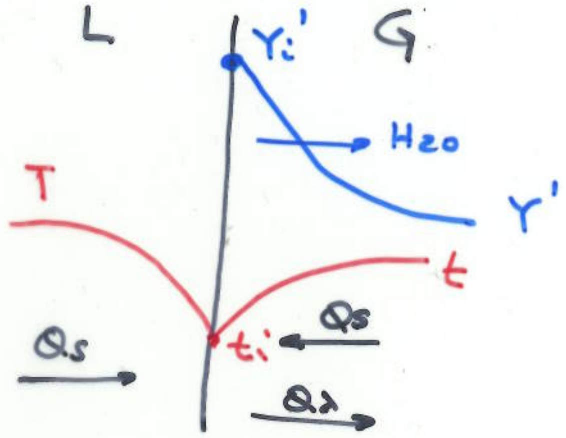


Perfiles T, t ; Y'

Tope Torre



Fondo Torre



El agua puede enfriarse a $T <$ a la del aire siempre que $T > t_W$

Para el diseño de las torres de enfriamiento se calcula la C_R (característica requerida) para ≠ valores de G

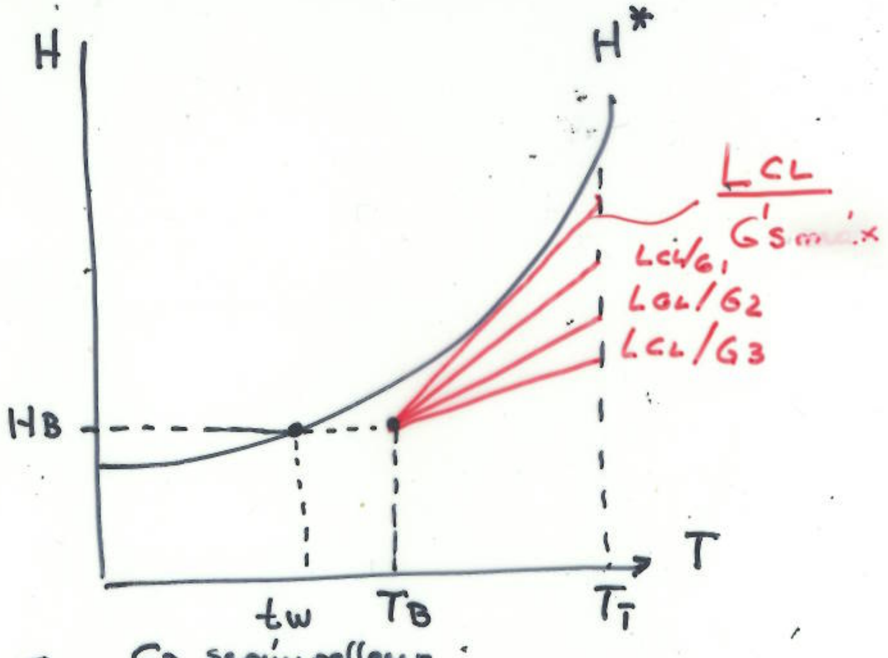
Los fabricantes entregan C_D (característica disponible) de sus rellenos también función de L y G.

L → dato

ΔT → dato

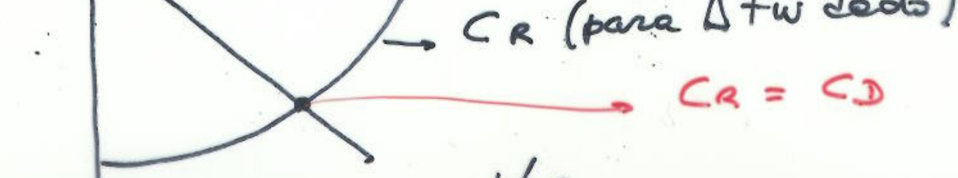
H_B → dato

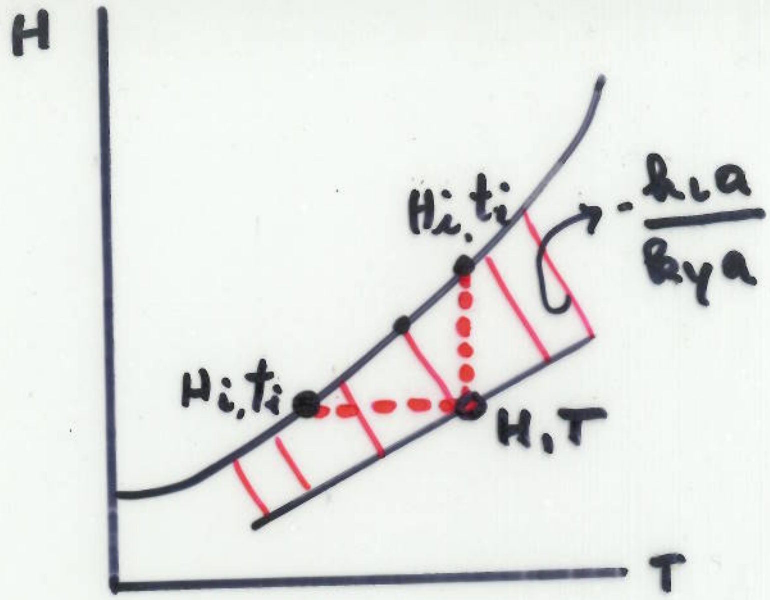
En realidad T_B se define con Δt_W



$$C_D = \frac{k_y a V}{L}$$

$$C_R = \int_{T_B}^{T_L} \frac{c_L\, dT}{H_i - H}$$





gotas:

$$\frac{h_L a}{k_y a\, c_L} : 1{,}3 - 5$$

Película:

$$\frac{h_L a}{k_y a\, c_L} : 10 - 160$$

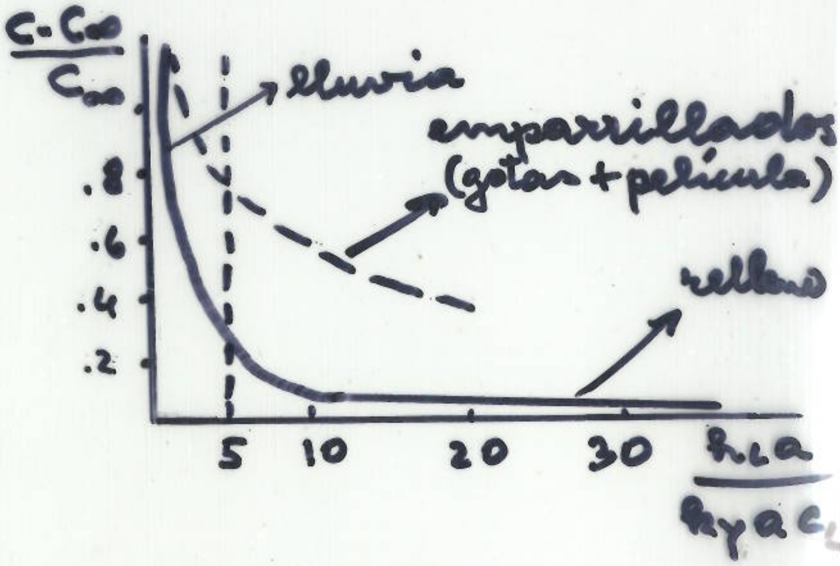
$$h_L \to 0 \qquad \frac{1}{h_L} \to \infty \qquad t_i = t_W \qquad (H_i - H) = 0$$

$$h_L \to \infty \qquad \frac{1}{h_L} \to 0 \qquad t_i = T \qquad H_i = H_S = H^*_T$$

$$(H_i - H) = (H^* - H) = \text{máx.}$$

$$C_\infty = \int_{T_B}^{T_r} \frac{c_L\, dT}{H^* - H} = \frac{K_y a V}{L}$$

$$C = \int_{T_B}^{T_r} \frac{c_L\, dT}{H_i - H} = \frac{k_y a V}{L}$$

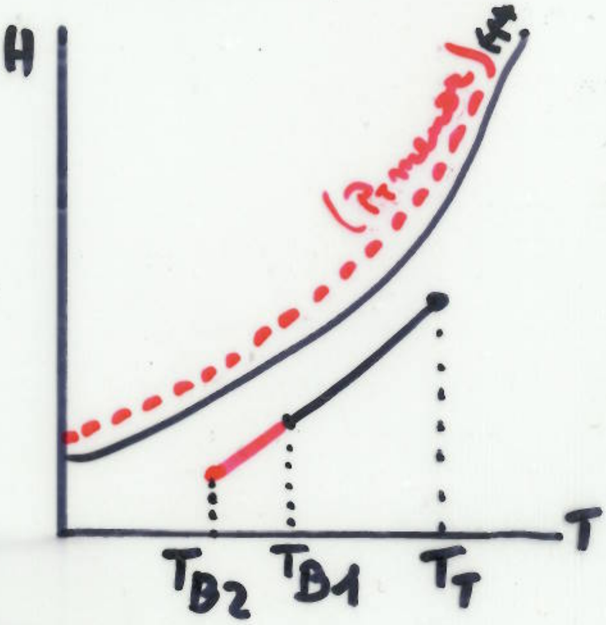


– En torres de película $\frac{C - C_\infty}{C_\infty} < 2\% \Rightarrow C \cong C_\infty$

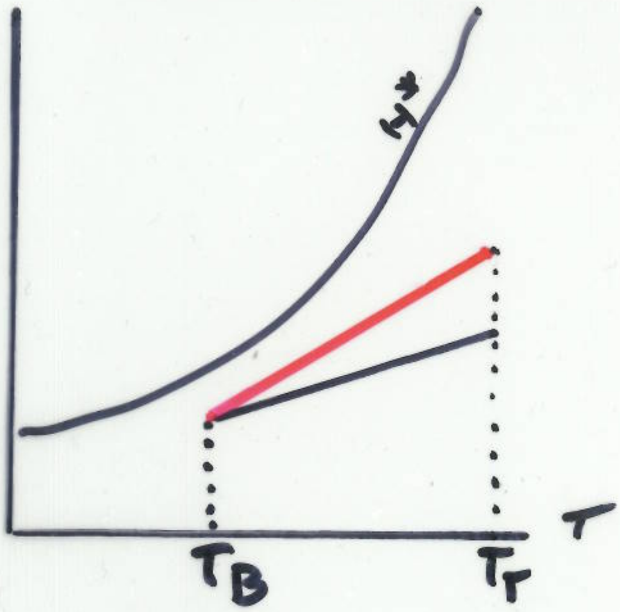
t_i, Y_i, H_i sobre la curva de equilibrio.

Dependen de h_L, k_y, H y T

$\Delta T_2 > \Delta T_1$

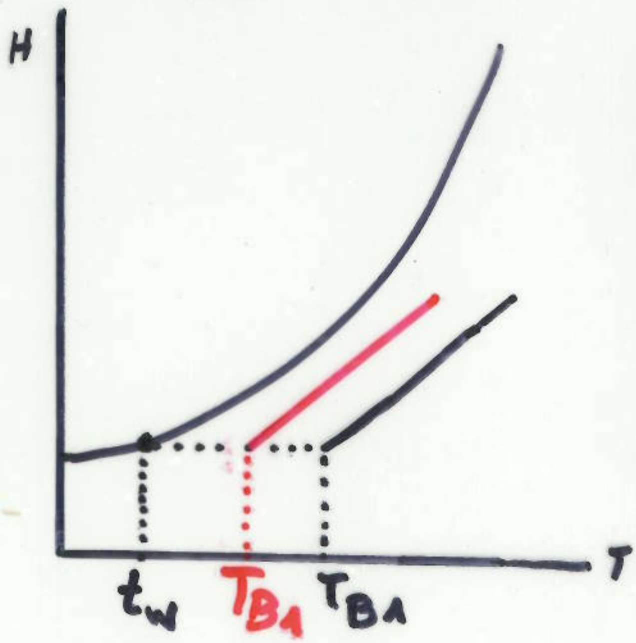


$(L/G'_s)_2 > (L/G'_s)_1$

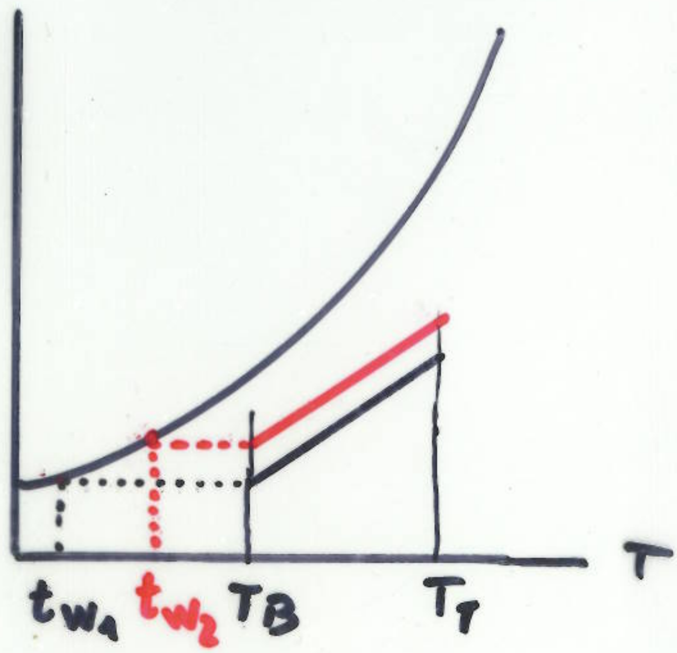


Performance o Rendimiento

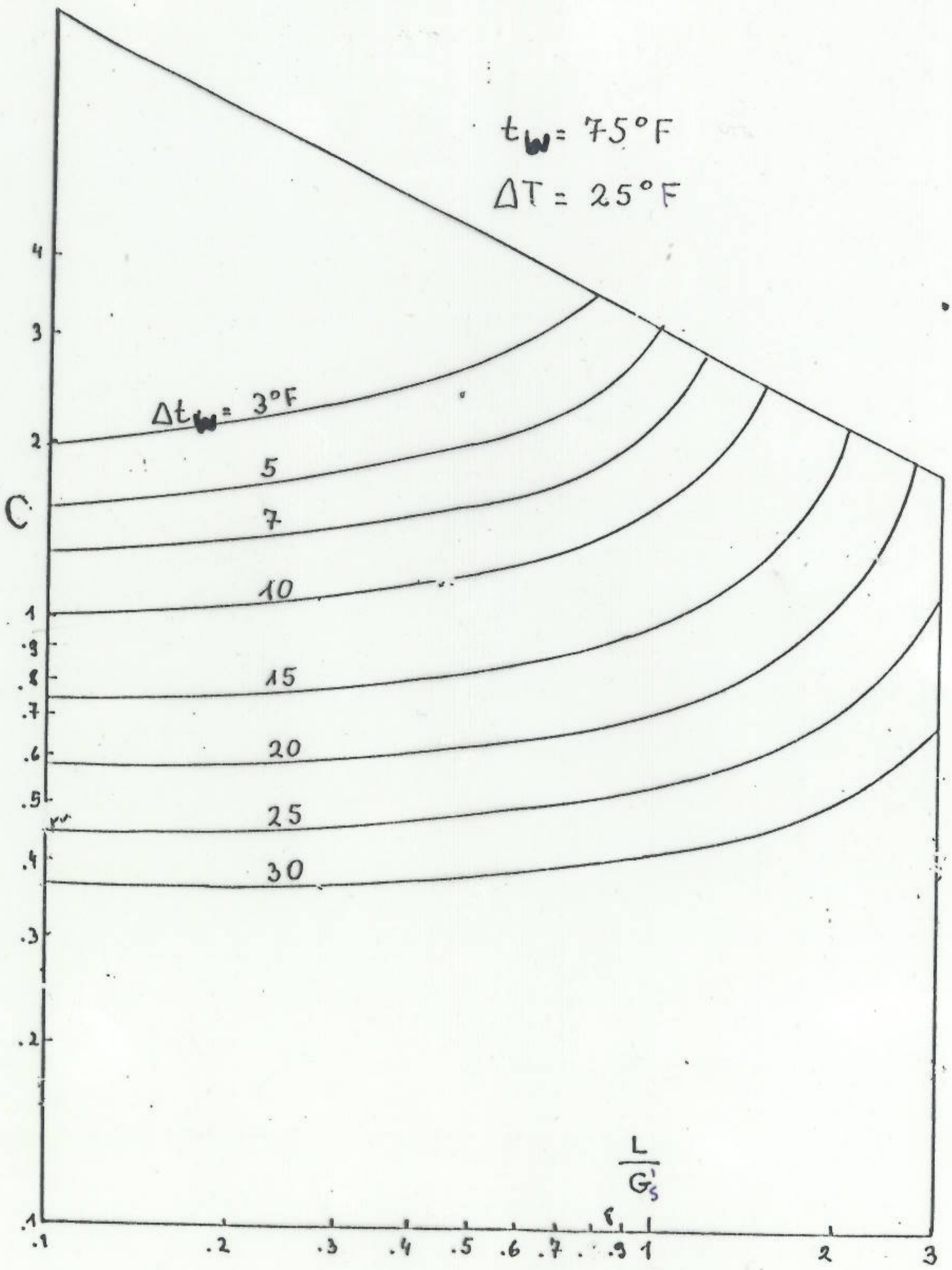
$\Delta t_{w2} < \Delta t_{w1}$



$t_{w2} > t_{w1}$

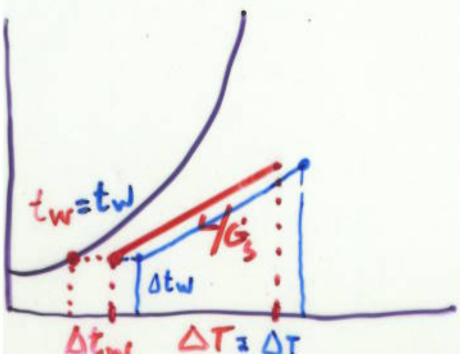


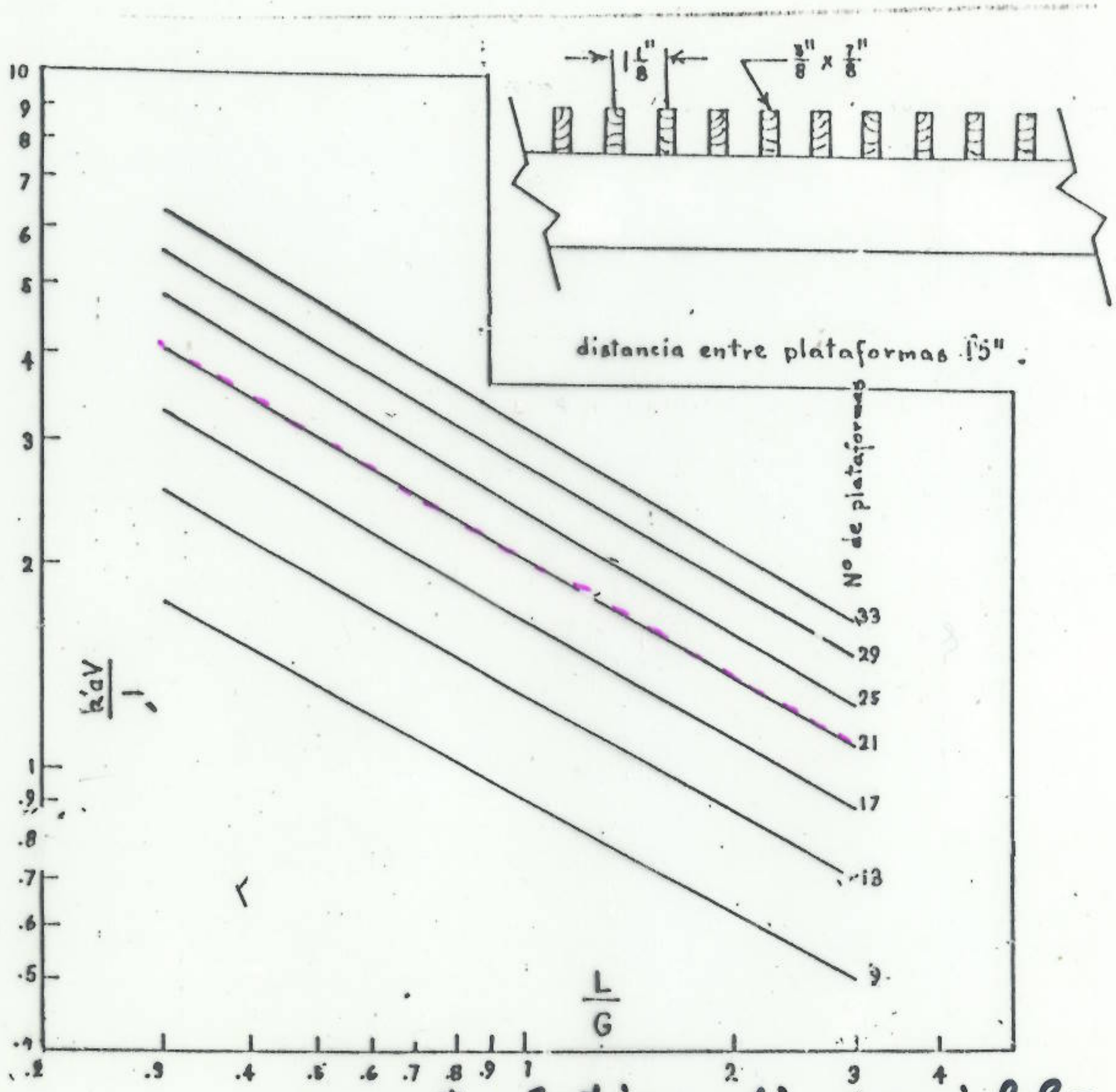
Variable operativa: G'_s



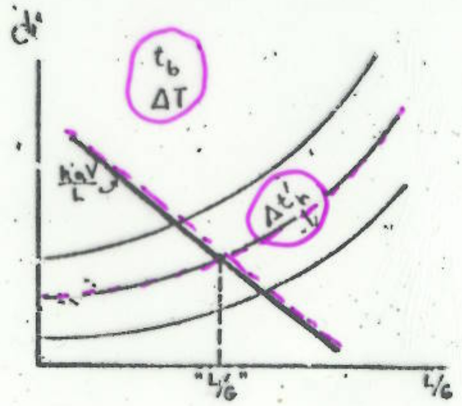
curvas teóricas de performance

$$C = \int_{T_B}^{T_T} \frac{c_L\, dT}{H^* - H} = f\left(\Delta T, \Delta t_W, \frac{L}{G'_s}, t_W\right)$$





característica disponible



Método de Mickley: Evolución del aire

H vs. t

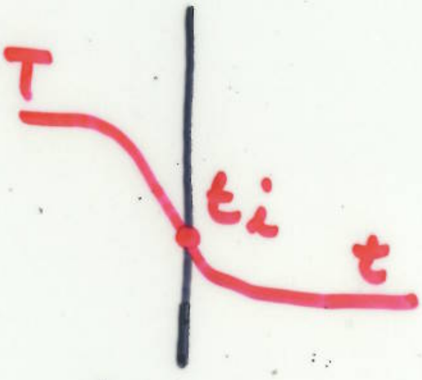
$$H = c_s (t - t_0) + \lambda_0 Y'$$

en el ga

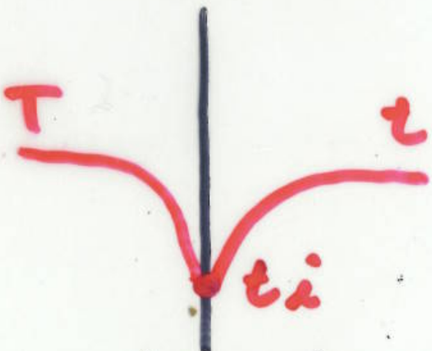
$$\boxed{\begin{aligned} dQ &= G'_s\, dH = k_Y a (H_i - H)\, dV \\ dQ_s &= G'_s c_s\, dt = h a (t_i - t)\, dV \end{aligned}}$$

$$\frac{dH}{c_s\, dt} = \frac{k_Y a}{h a} \; \frac{H_i - H}{t_i - t}$$

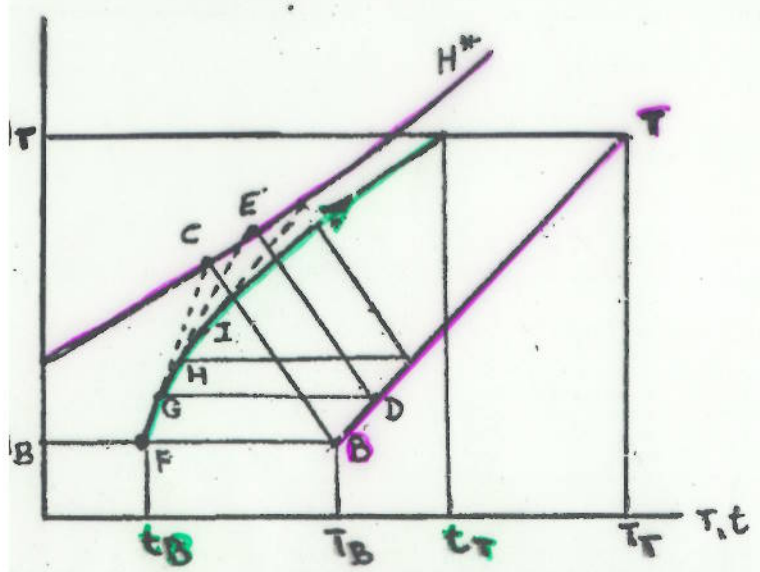
$$Le = \frac{h}{k_Y c_s} = 1 \qquad \therefore \frac{dH}{dt} = \frac{H_i - H}{t_i - t}$$

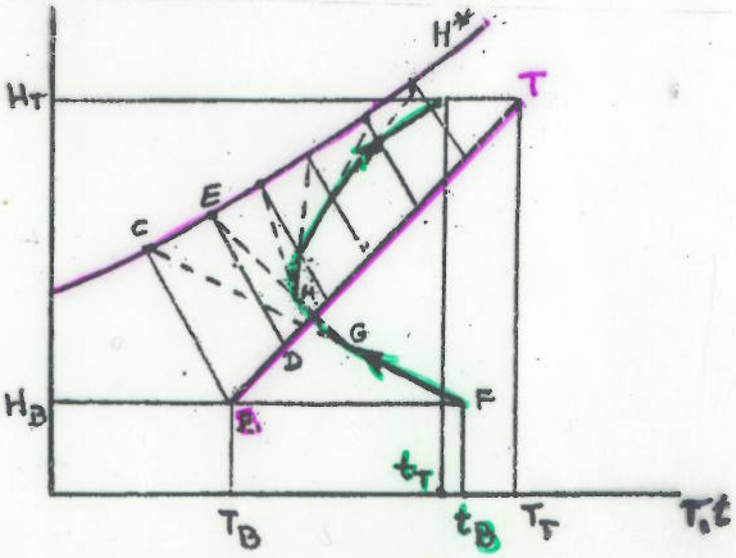


$t_i > t$



$t_i < t$





Aplicación

Datos:

V

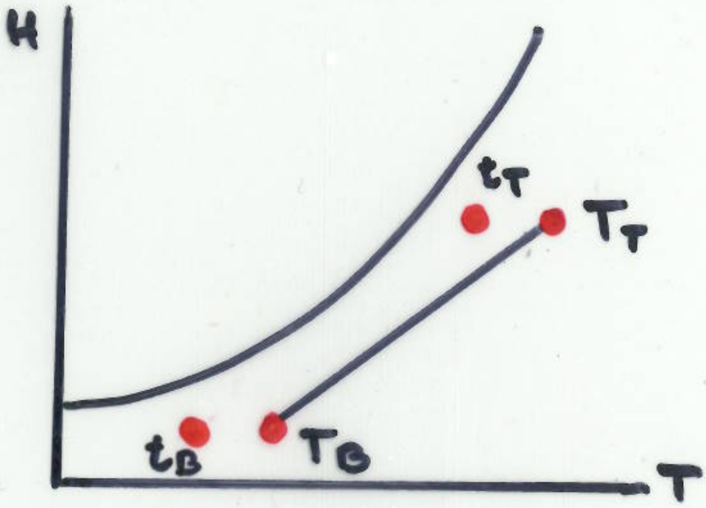
G'_S

L

$T_T \quad T_B$

$t_T \quad t_B$

t_w



1) Determinación de coeficientes.

a) suponer h_La/k_Ya y trazar "Mickley"
Repetir hasta lograr t_T

b) Calcular

$$\int_{H_B}^{H_T} \frac{dH}{H_i - H} = \frac{k_Y a}{G'_S} V \Longrightarrow k_Y a$$

c) de $-\dfrac{h_L a}{k_Y a} \Longrightarrow h_L a$

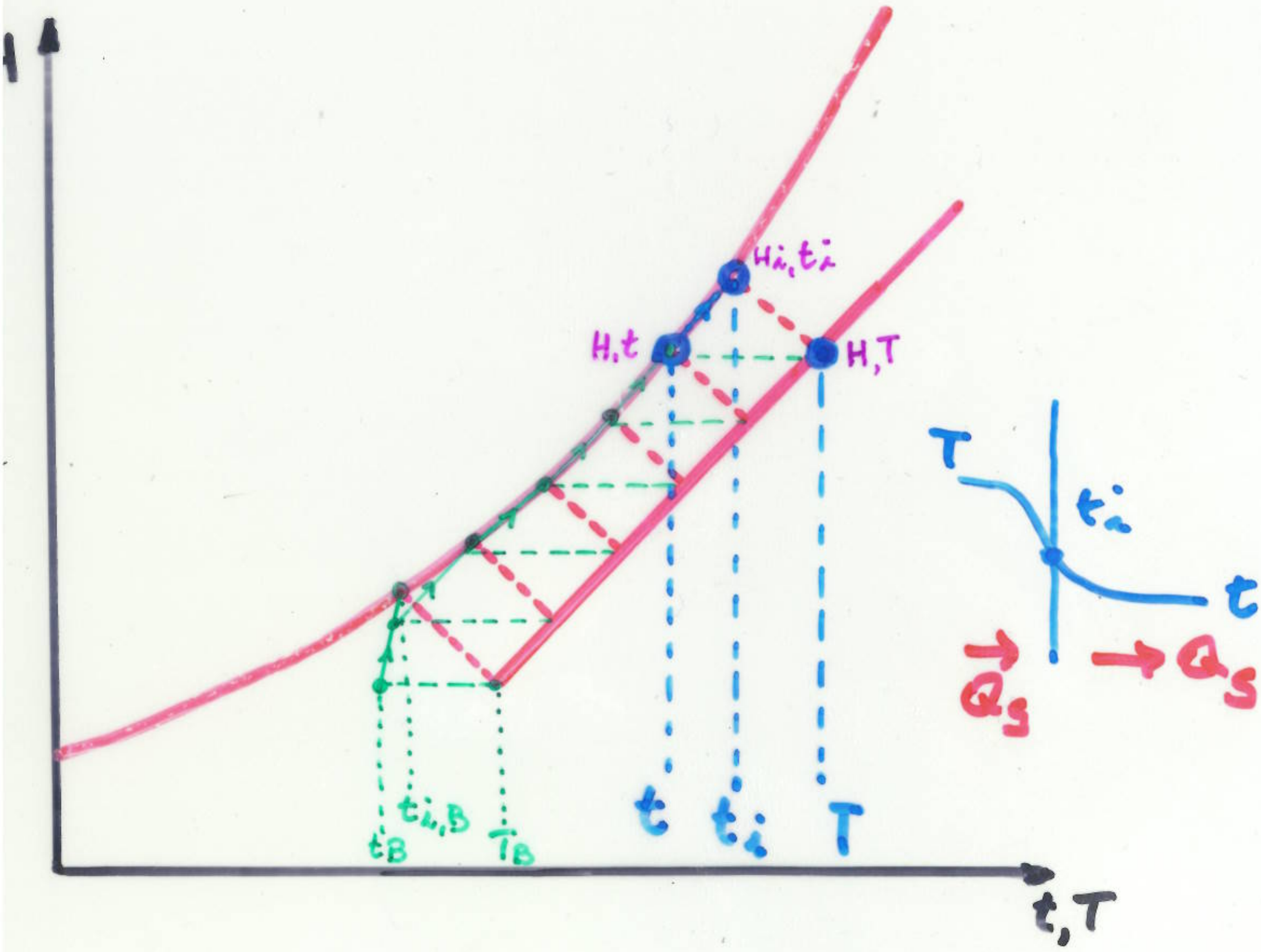
d) de $Le = \dfrac{h}{k_Y c_S} \Longrightarrow h$

2) Agua de reposición

$$H_T = c_S (t_T - t_0) + \lambda_0 Y'_T \Longrightarrow Y'_T$$

$$L = G'_S (Y'_T - Y'_B) \approx G'_S Y'^{*}_T$$

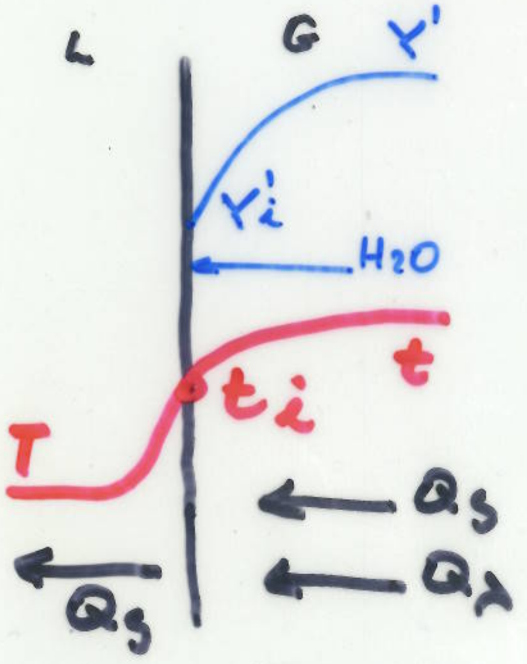
3) Formación de Niebla

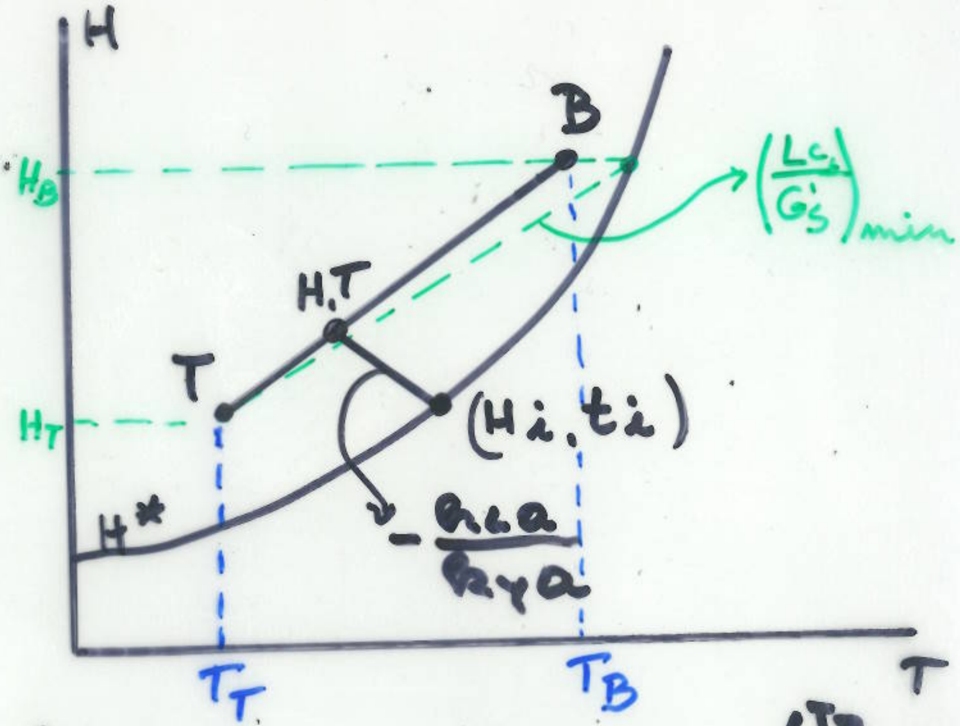


Formación de Niebla

Deshumidificación

$$dQ = k_Y a \,(H - H_i)\, dV$$





$$\int_{H_T}^{H_B} \frac{dH}{H - H_i} = \frac{k_Y a}{G'_S} V \qquad \frac{k_Y a}{L} V = \int_{T_T}^{T_B} \frac{c_L\, dT}{H - H_i}$$