

A.08.02 – Misturas Gás-Vapor e Condicionamento de Ar

Fenômenos de Saturação do Vapor no Ar

Prof. C. Naaktgeboren, PhD



<https://github.com/CNThermSci/ApplThermSci>

Compiled on 2021-03-02 14h52m16s UTC

1 Temperatura do Ponto de Orvalho

• Saturação Adiabática e Temperatura de Bulbo Úmido

- Saturação Adiabática
- Temperatura de Bulbo Úmido
- Psicrômetro Giratório

3 Referências e Tópicos de Leitura

Esta apresentação baseia-se nas referências [1], Seções 14-3 a 14-4 (tópicos de leitura) e [2].

Temperatura do Ponto de Orvalho, T_{po}

Definition

Temperatura de ponto de orvalho é definida como a temperatura na qual se dá o **início da condensação** quando o ar é resfriado à **pressão constante**.



Processo de resfriamento a pressão constante desde a temperatura inicial, T_1 , até a temperatura do ponto de orvalho, T_{po} . Diagrama em escala
Fonte: autoria própria

Temperatura do Ponto de Orvalho, T_{po}



cl.staticflickr.com



Processo de resfriamento a pressão constante desde a temperatura inicial, T_1 , até a temperatura do ponto de orvalho, T_{po} . Diagrama em escala

Fonte: autoria própria

Temperatura do Ponto de Orvalho, T_{po}



upload.wikimedia.org



Processo de resfriamento a pressão constante desde a temperatura inicial, T_1 , até a temperatura do ponto de orvalho, T_{po} . Diagrama em escala

Fonte: autoria própria

Temperatura do Ponto de Orvalho, T_{po}



www.liquidimageco.com



www.quora.com

Temperatura do Ponto de Orvalho, T_{po}



images.pexels.com

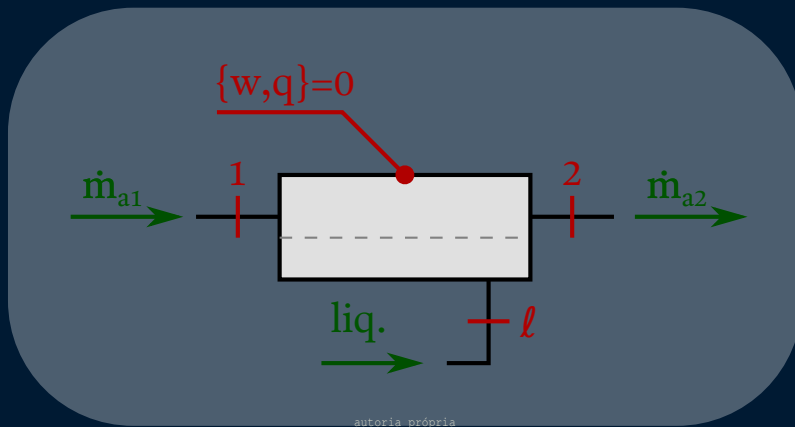


images.pexels.com

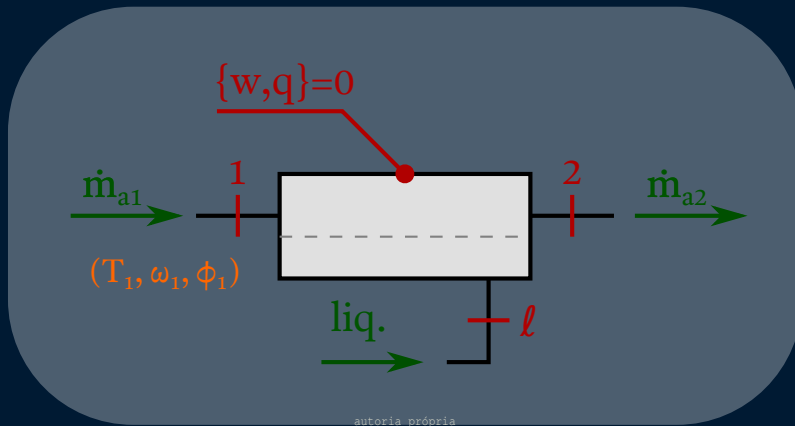
Saturação Adiabática

- Pressão parcial é um conceito de difícil medição direta;
- É desejável relacionar as umidades a grandezas de fácil medição;
- A medição da temperatura de orvalho, T_{po} , não é muito prática;
- Estuda-se então o processo de saturação adiabática:

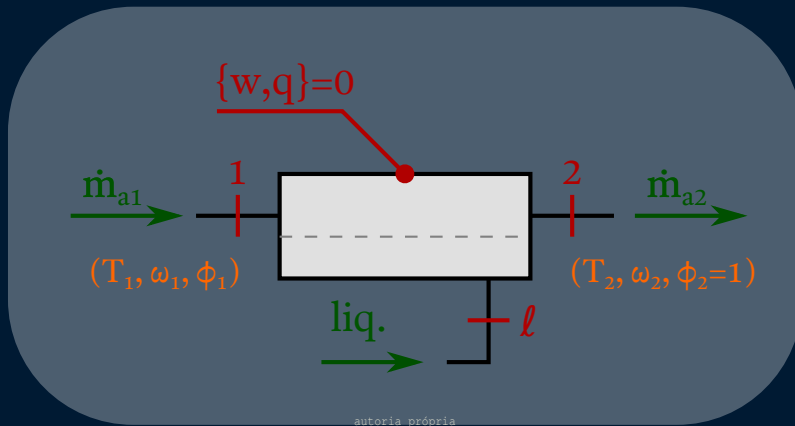
Saturação Adiabática



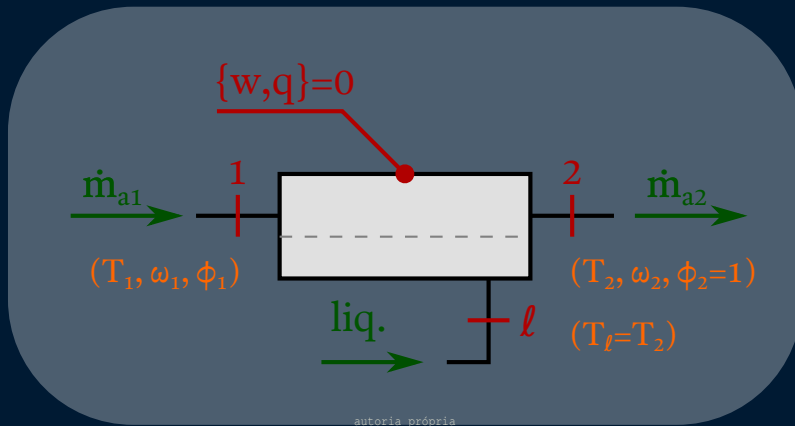
Saturação Adiabática



Saturação Adiabática

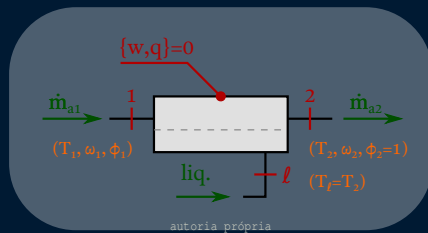


Saturação Adiabática



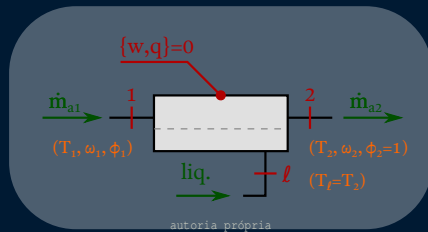
Balanco de Massa

$$\dot{m}_{a1} = \dot{m}_{a2}$$



Balanco de Massa

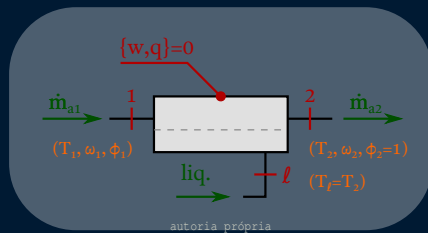
$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$



Balanco de Massa

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$

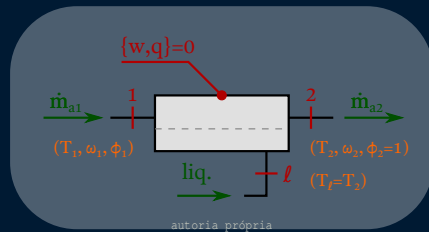
$$\dot{m}_{w1} + \dot{m}_l = \dot{m}_{w2}$$



Balço de Massa

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$

$$\dot{m}_{w1} + \dot{m}_l = \dot{m}_{w2} \quad \rightarrow$$

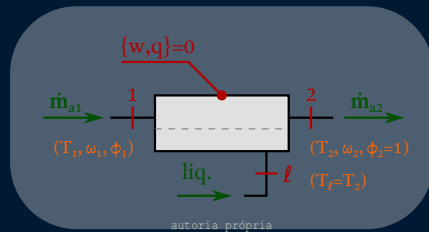


Balanco de Massa

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$

$$\dot{m}_{w1} + \dot{m}_\ell = \dot{m}_{w2} \quad \rightarrow$$

$$\dot{m}_a \omega_1 + \dot{m}_\ell = \dot{m}_a \omega_2$$

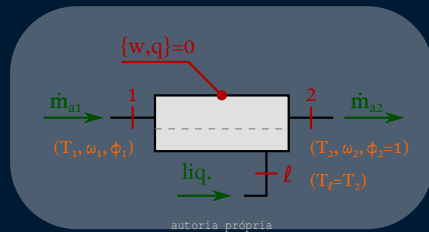


Balanco de Massa

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$

$$\dot{m}_{w1} + \dot{m}_\ell = \dot{m}_{w2} \quad \rightarrow$$

$$\dot{m}_a \omega_1 + \dot{m}_\ell = \dot{m}_a \omega_2 \quad \rightarrow$$



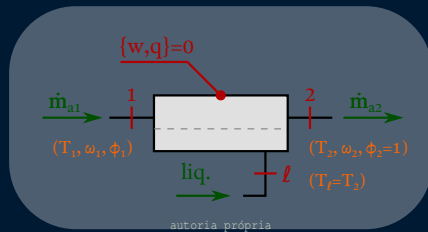
Balanco de Massa

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \quad (\text{ar seco})$$

$$\dot{m}_{w1} + \dot{m}_\ell = \dot{m}_{w2} \quad \rightarrow$$

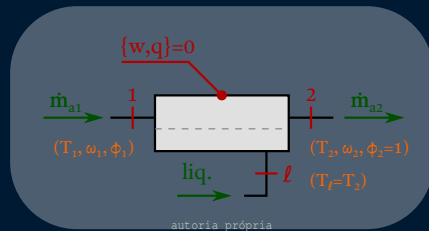
$$\dot{m}_a \omega_1 + \dot{m}_\ell = \dot{m}_a \omega_2 \quad \rightarrow$$

$$\dot{m}_\ell = \dot{m}_a (\omega_2 - \omega_1).$$



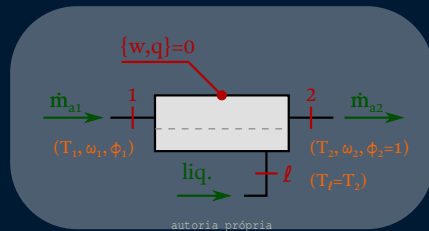
Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai}$$



Balanco de Energia (com $Q = W = 0$)

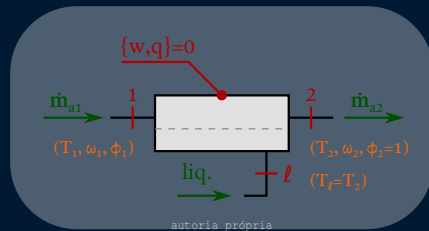
$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$



Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

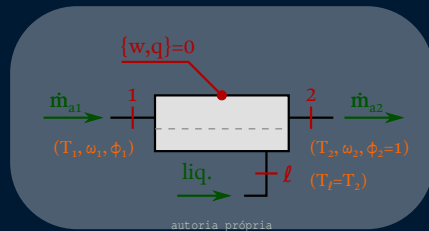
$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2$$



Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

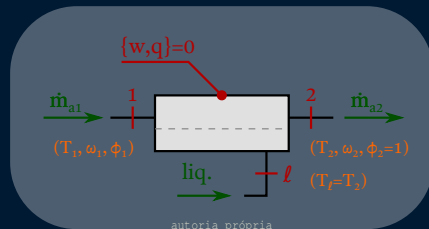


Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2$$

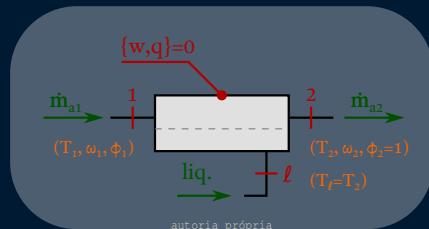


Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2 \quad \rightarrow$$



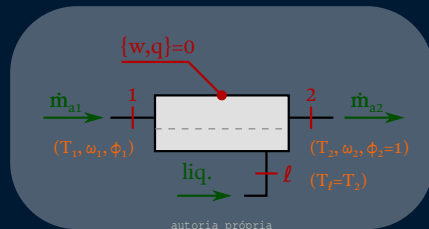
Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$h_1 + (\omega_2 - \omega_1) h_\ell = h_2$$



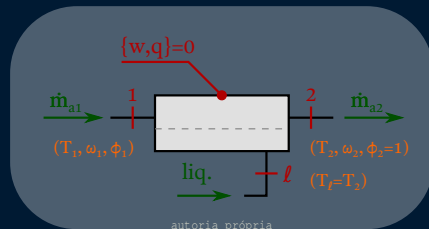
Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$h_1 + (\omega_2 - \omega_1) h_\ell = h_2 \quad \rightarrow$$



Balanco de Energia (com $Q = W = 0$)

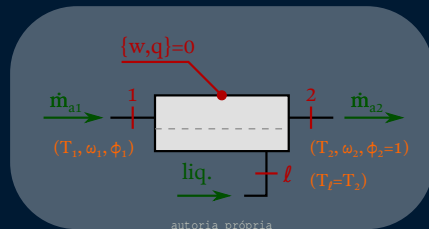
$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$h_1 + (\omega_2 - \omega_1) h_\ell = h_2 \quad \rightarrow$$

$$(c_P T_1 + \omega_1 h_{v1}) + (\omega_2 - \omega_1) h_\ell = (c_P T_2 + \omega_2 h_{g2})$$



Balanco de Energia (com $Q = W = 0$)

$$\dot{E}_{ent} = \dot{E}_{sai} \quad \rightarrow$$

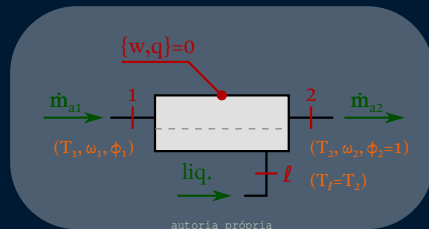
$$\dot{m}_a h_1 + \dot{m}_\ell h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$\dot{m}_a h_1 + \dot{m}_a (\omega_2 - \omega_1) h_\ell = \dot{m}_a h_2 \quad \rightarrow$$

$$h_1 + (\omega_2 - \omega_1) h_\ell = h_2 \quad \rightarrow$$

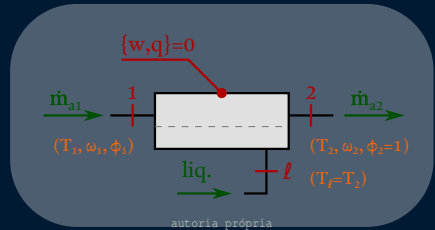
$$(c_P T_1 + \omega_1 h_{v1}) + (\omega_2 - \omega_1) h_\ell = (c_P T_2 + \omega_2 h_{g2})$$

$$\omega_2 = \frac{0,622 P_{g2}}{P - P_{g2}}; \quad \omega_1 = \frac{c_P (T_2 - T_1) + \omega_2 h_{lg2}}{h_{v1} - h_\ell}.$$



Exemplo: Ar entrando com $\phi_1 = 100\%$

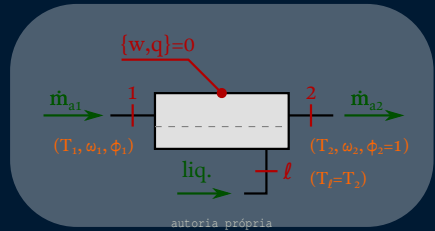
$$\dot{m}_\ell = \dot{m}_a(\omega_2 - \omega_1) = 0 \text{ kg/s} \quad (\text{sat.})$$



Exemplo: Ar entrando com $\phi_1 = 100\%$

$$\dot{m}_\ell = \dot{m}_a(\omega_2 - \omega_1) = 0 \text{ kg/s} \quad (\text{sat.}) \quad \rightarrow$$

\rightarrow

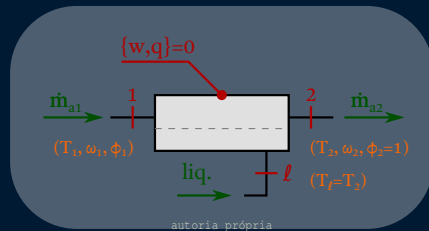


Exemplo: Ar entrando com $\phi_1 = 100\%$

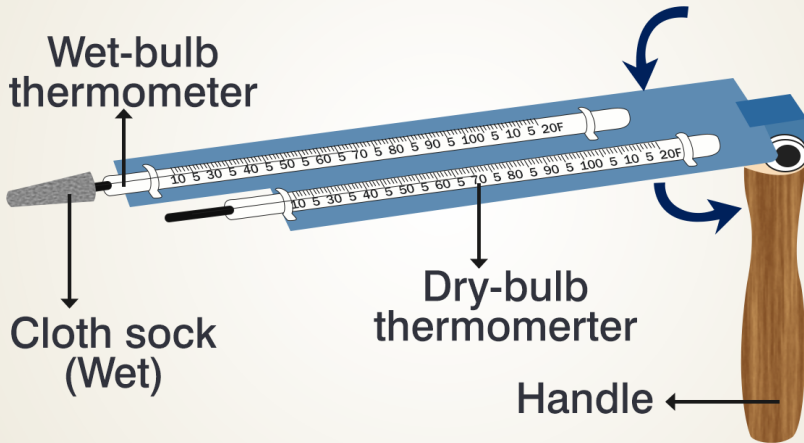
$$\dot{m}_\ell = \dot{m}_a(\omega_2 - \omega_1) = 0 \text{ kg/s} \quad (\text{sat.}) \quad \rightarrow$$

$$\omega_1 = \omega_2; \quad \rightarrow$$

$$\omega_1 = \omega_2$$



Sling Psychrometer



Referências – I

- [1] Y. A. Çengel and M. A. Boles.
Termodinâmica.
AMGH, Porto Alegre, 7th edition, 2013.
- [2] D. L. Fenton.
Fundamentals of refrigeration: A course book for self-directed or group learning.
ASHRAE, second edition edition, 2016.



Photo by Francesco Ungaro from Pexels

<https://www.pexels.com/photo/mountains-under-dark-clouds-in-evening-5592630/>