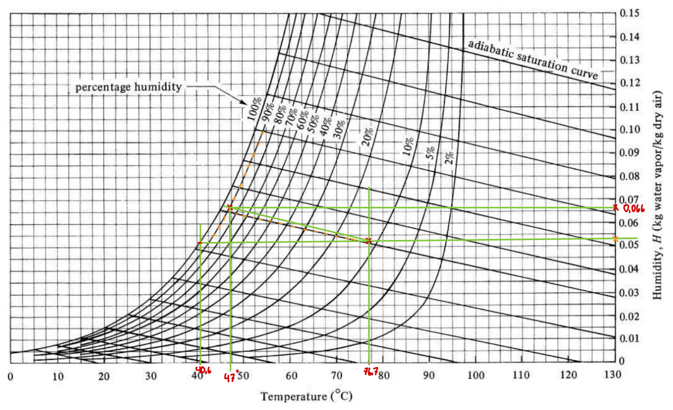
# Øving 11

## 1

Air enters an adiabatic saturator having a temperature of 76.7 °C and a dew-point temperature of 40.6 °C. It leaves the saturator 90 % saturated. What are the final values of H and T °C?

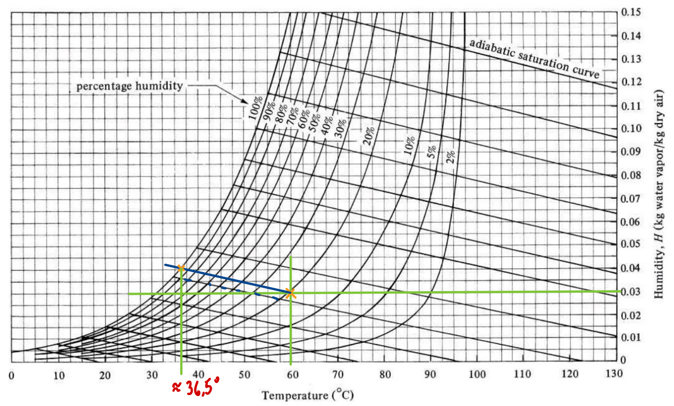



$T_{ut} = 47°C$

$H_{ut} = 0{,}066$ kg $H_2O$/kg dry air

## 2

The humidity of an air-water vapor mixture is H = 0.030 kg $H_2O$/dry air. The dry bulb temperature of the mixture is 60 °C. What is the wet bulb temperature?




$T \approx 36{,}5\,°C$

## 3

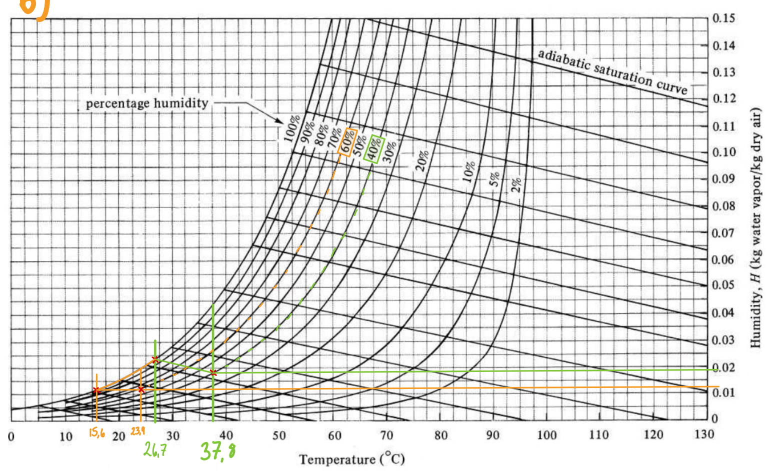
Air having a dry bulb temperature of 37.8 °C and a wet bulb of 26.7 °C is to be dried by first cooling to 15.6 °C to condense water vapor and then heating to 23.9 °C.

a) Calculate the initial humidity and percentage humidity.

b) Calculate the final humidity and percentage humidity. [Hint: Locate the initial point on the humidity chart. Then go horizontally (cooling) to the 100 % saturation line. Follow this line to 15.6 °C. Then go horizontally to the right to 23.9 °C].

a)

b)



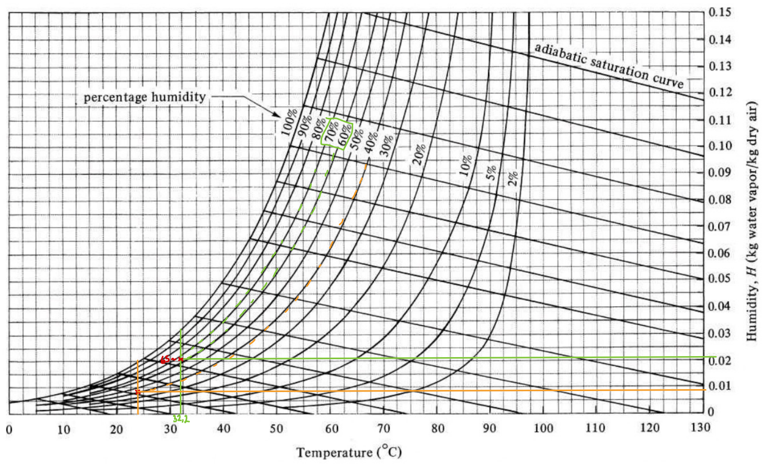

a) Ved start: $H_R = 40\%$, $H = 0{,}018$ kg $H_2O$/kg tørr luft

b) Ved slutt: $H_R = 60\%$, $H = 0{,}012$ kg $H_2O$/kg tørr luft

# 4

Air entering an adiabatic cooling chamber has a temperature of 32.2 °C and a percentage humidity of 65 %. It is cooled by a cold water spray and saturated with water vapor in the chamber. After leaving, it is heated to 23.9 °C. The final air has a percentage humidity of 40 %.

a) What is the initial humidity in the air?
b) What is the final humidity after heating?




a) $H = 0{,}021$ kg $H_2O$/kg tørr luft

b) $H = 0{,}008$ kg $H_2O$/kg tørr luft

# 5

A batch of wet solid was dried on a tray dryer using constant drying conditions and a thickness of material on the tray of 25.4 mm. Only the top surface was exposed. The drying rate during the constant-rate period was R = 2.05 kg $H_2O$/h $m^2$. The ratio $L_s/A$ used was 24.4 kg dry solid/$m^2$ exposed surface. The initial free moisture was $X_1$ = 0.55 and the critical moisture content $X_c$ = 0.22 kg free moisture/kg dry solid.

Calculate the time to dry a batch of this material from $X_1$ = 0.45 to $X_2$ = 0.30 using the same drying conditions but a thickness of 50.8 mm, with drying from the top and bottom surfaces.

Siden $X_1, X_2 > X_c$, er R konstant

$$R = -\frac{L_s}{A}\frac{dX}{dt} \Rightarrow dt = -\frac{L_s}{R \cdot A} dX$$ / Integrerer

$$t = \frac{L_s}{R \cdot A}(X_1 - X_2)$$

/ Tykkelsen er doblet, kan anta at $L_s = 2 \cdot L_{s,gammel}$
Siden vi tørker fra topp og bunn er $A_{ny} = 2 \cdot A_{gammel}$

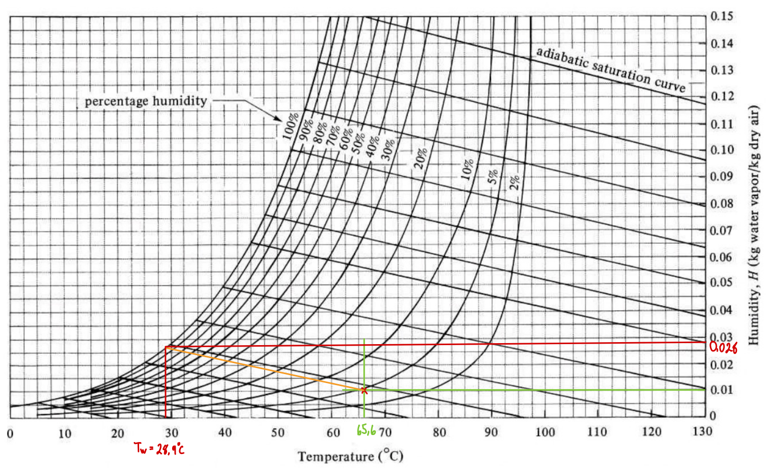
$$\frac{L_s}{A} = \frac{2 \cdot L_{s,gammel}}{2 \cdot A_{gammel}} = \frac{L_{s,g}}{A_g} = 24{,}4$$

$$t = \frac{24{,}4}{2{,}05}(0{,}45 - 0{,}30)$$

$$t = 1{,}79 \text{ h}$$

# 6

An insoluble wet granular material is dried in a pan 0.457 x 0.457 m (1.5 x 1.5 ft) and 25.4 mm deep. The material is 25.4 deep in the pan, and the sides and bottom can be considered to be insulated. Heat transfer is by convection from an air stream flowing parallel to the surface at a velocity of 6.1 m/s (20 ft/s). The air is at 65.6 °C (150 °F) and has a humidity of 0.010 kg $H_2O$/kg dry air. Estimate the rate of drying for the constant-rate period.




$H_w = 0{,}028$

$T_w = 28{,}9$

* Import studass * (kan utledes fra ideell gasslov og $H = \frac{18{,}02}{28{,}97} \cdot \frac{P_A}{P - P_A}$)

Calculating the humid air volume:

$$v_H\left(\frac{m^3}{kg\ dry\ Air}\right) = \frac{22.41}{273} * T(K) * \left(\frac{1}{28.97} + \frac{1}{18.02}H\right)$$

($T(K) = 65{,}6 + 273{,}15$, $H = 0{,}01$)

$\Rightarrow V_H = 0{,}97529$ $m^3$/kg tørr luft

Tettheten for lufta (1 kg tørr + 0,01 kg $H_2O$)

$$\rho = \frac{1 + 0{,}01}{0{,}975} = 1{,}038 \text{ kg/m}^3$$

* Import stud.ass:

Using the following correlation to calculate the heat transfer coefficient, only valid for the parameters in the following ranges: Temperature T: 45 - 150 °C, Mass flow velocity G: 2,450 – 29,300 kg/h m² and a gas velocity of 0.61 – 7.6 m/s.

$$h = 0.0204G^{0.8}$$

$$\rho \cdot u = G = 6{,}1 \cdot 3600 \cdot 1{,}038 = 22794 \ \frac{kg}{h\,m^2}$$

(s → h)

$$h = 0{,}0204 \cdot 22794^{0{,}8} = 62{,}50 \ \frac{W}{m^2 K}$$

$$R_c = \frac{h}{\lambda_w}(T - T_w) \cdot 3600$$

$\lambda_w = \Delta H_{vap, H_2O}$ : *Import studass*  At $T_w$ = 28.9 °C, the heat of vaporization of water (from steam tables) $\lambda_w$ = 2 433 kJ/kg.

$$R_c = \frac{62{,}5 \ \frac{W}{m^2 K}}{2433 \cdot 1000 \ J/kg} (65{,}6 - 28{,}9)\ K \cdot 3600\ s/h$$

$R_c = 3{,}394$ kg/h·m²

Total rate:

$R_c A = 3{,}394 \cdot 0{,}457^2 = 0{,}709$ kg/h

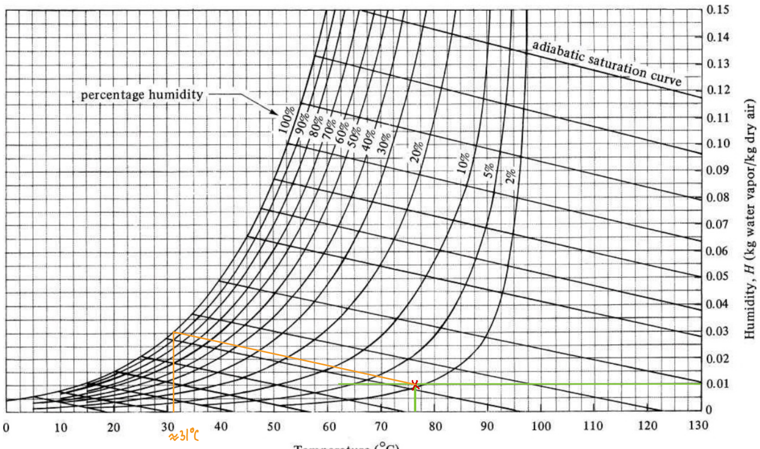
**7**

Using the conditions of Problem 6 for the constant-rate drying period, do as follows.

a) Predict the effect on $R_C$ if the air velocity is only 3.05 m/s.
b) Predict the effect if the gas temperature is raised to 76.7 °C and H remains the same.
c) Predict the effect on the time *t* for drying between moisture contents $X_1$ to $X_2$ if the thickness of material dried is 38.1 mm instead of 25.4 mm and the drying is still in the constant-rate period.

a) Basert på formlene, vil ny $R_c = \left(\frac{3{,}05}{6{,}1}\right)^{0{,}8} \cdot R_{c,gammel} = 0{,}5^{0{,}8} \cdot 3{,}394 = 1{,}949 \ \frac{kg}{m^2 \cdot h}$

b)




⇓

Studass: $\lambda_w = 2428{,}12$ kJ/kg

Ny $V_H = 1{,}00725$ m³/kg luft

Ny $\rho = 1{,}00272$ kg/m³

$$h = 0{,}0204 \cdot (1{,}00272 \cdot 6{,}1 \cdot 3600)^{0{,}8} = 60{,}797 \ \frac{W}{m^2 K}$$

$$R_c = \frac{60{,}797 \ \frac{W}{m^2 K}}{2428{,}12 \cdot 1000 \ J/kg} (76{,}7 - 31) \cdot 3600 \ s/h = 4{,}12 \ kg/h \cdot m^2$$

c) Fra tidligere, for "constant rate": $R_c$ er konstant

$t = \frac{L_s}{A \cdot R_c}(X_1 - X_2)$ , $L_s$ er proporsjonal med $d \Rightarrow L_s = \frac{d_{ny}}{d_{gammel}} \cdot L_{s,gammel}$

$$\Rightarrow t_2 = \frac{\frac{38{,}1}{25{,}4} \cdot L_{s,gammel}}{A \cdot R_c} \cdot (X_1 - X_2)$$

$\Rightarrow t_2 = 1{,}5 \cdot t_1$