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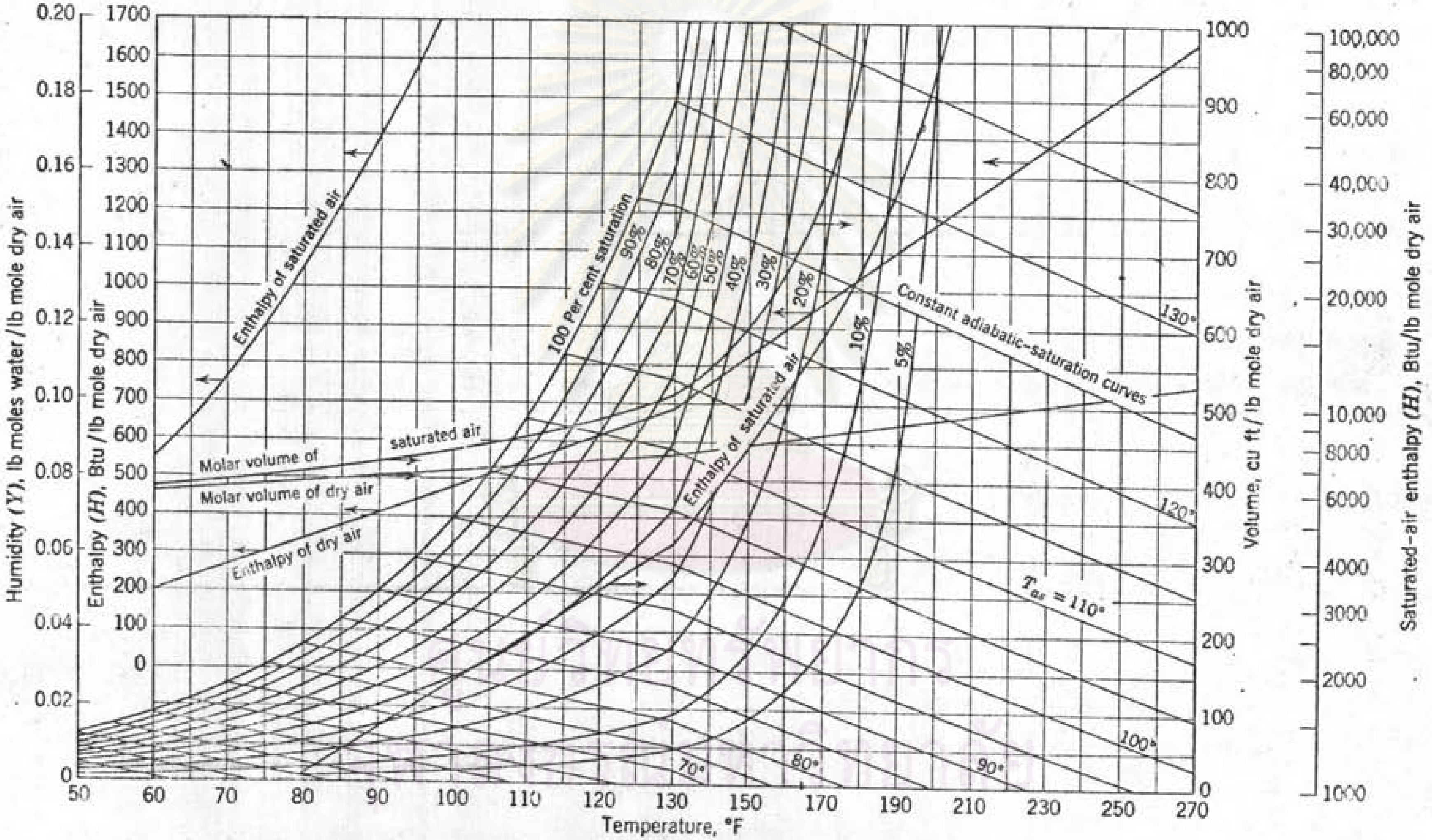
NOMENCLATURE

A:	cross-sectional area	(m^2)
a:	specific surface area	(m^2/m^3)
C:	local moisture content	(kg/kg dry solid)
C_a:	specific heat of dry air	(kcal/kg^{o}C)
C_p:	specific heat of dry material	(kcal/kg^{o}C)
C_v:	specific heat of water vapor	(kcal/kg^{o}C)
C_w:	specific heat of liquid water	(kcal/kg^{o}C)
C_H:	C_a+C_vH	(kcal/kg^{o}C)
C_m:	C_p+C_wC	(kcal/kg^{o}C)
$H(r,x,t)$:	air humidity	(kg/kg-dry air)
H^*_m:	saturation air humidity at the wet bulb temperature	(kg/kg-dry air)
h :	heat transfer coefficient	(kcal/m^2.sec^{o}C)
k_H:	mass transfer coefficient	(kg/m^2.sec.ΔH)
L :	bed height	(m)
m :	weight of material at time t	(kg)
m_d:	weight of dry solid	(kg)
p :	production rate	(kg/hr)
R_c:	constant drying rate	(kg.water/m^2.hr)
R_d:	falling drying rate	(kg.water/m^2.hr)
R :	overall drying rate	(kg-water/m^3-bed.hr)
R_w:	drying rate	(kg-water/kg dry-solid.hr)

$T(r,x,t)$	:	air temperature	(^{o}C)
T_m	:	material temperature (assume uniform termperature within material)	(^{o}C)
t	:	time	(sec)
V	:	superficial velocity	(m/sec)
W	:	average moisture content (d.b)	(kg/kg-dry material)
W_c	:	critical moisture content (d.b)	(kg/kg-dry material)
W_e	:	equilibrium moisture content (d.b)	(kg/kg-dry material)
ρ	:	density of dry air	(kg/m^3)
ρ_b	:	bulb density of dry material	(kg/m^3)
ρ_s	:	density of dry material	(kg/m^3)
Θ_c	:	drying time in constant drying rate	(hr)
θ_d	:	drying time in falling drying rate	(hr)
θ	:	overall drying time	(hr)
ε	:	bed voidage	
γ_w	:	latent heat	(kcal/kg)

HUMIDITY CHART FOR THE AIR-WATER SYSTEM



APPENDIX B-1

Determination of Moisture Content

This is an illustration of how the moisture content was determined.

Run No. A-2:

Sample weight = 331.1 g

Dry sample weight = 41.33 g

Moisture weight = 331.1-41.33 g

= 289.87 g

Moisture content = 289.87/41.33 kg water/kg dry solid

= 7.03 kg water/kg dry solid

At time = 10 min from start

Sample weight = 328.4 g

Moisture weight = 328.4-41.23 g

= 287.17 g

Moisture Content = 287.17/41.33 kg water/kg dry solid

= 6.948 kg water/kg dry solid

APPENDIX B-2

Determination of Drying Rate

Through it was possible to calculate the drying rate R_w from

$$\text{Drying rate } (R_w) = \frac{\text{weight of evaporated water}}{\text{weight of bone dry sample.time}}$$

It was found that a smooth moisture content VS. time curve should be drawn through the obtained data points first. Then the drying rate was found by drawing a tangent line to the curve and reading its slope.

APPENDIX B-3

Design Calculation of a Through Flow Dryer

Suppose we wish to reduce the moisture content of 100 kg/day (dry mass) of jujube from 678 % (dry basis) to 80 % (dry basis) in a through flow dryer. The density of dried jujube (ρ_s) is 805 kg/m^3. The hot air temperature is at 72^{o}C, air velocity 0.6 m/s and relative humidity 8 %. The bed voidage (ε) is 0.5 and bed height 0.08 m. Calculate the required drying time and dryer area.

The following data were obtained from our experiment:

Moisture Content	Drying Rate (R_w) = $-dw/d\theta$	$-d\theta/dw$
6.78	0.505	1.980
6.20	0.600	1.670
5.60	0.560	1.785
5.05	0.515	1.942
4.50	0.460	2.177
4.00	0.415	2.409
3.70	0.375	2.667
3.00	0.315	3.175
2.10	0.260	3.846
1.25	0.170	5.882
0.80	0.105	9.49

We find $\int_{w_1}^{w_2} -\frac{d\theta}{dw}\, dw = \theta_d$ by graphical integration

(See Figure 4.30)

The drying time = 19.1 hrs.

Since the voidage of bed = 0.5

and the density of dried jujube = 805 kg/m^3

the required bed volume = $\frac{P\theta}{\rho_s(1-\varepsilon)}$

$= \frac{(100/24)19.1}{805(1-0.5)}$

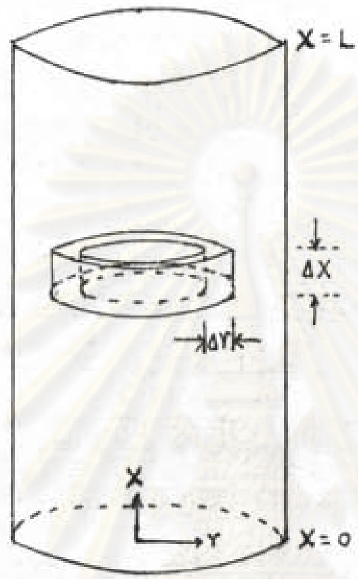
$= 0.1977\ m^3$

and the required area = $0.1977/0.08\ m^2$

$= 2.46 = 2.5\ m^2$

APPENDIX C

Microscopic Balances(Model) of Through-Flow Drying



Air Sensible Heat Balance:

$$\varepsilon 2\pi r\Delta r\Delta x\frac{\partial}{\partial t}(\rho C_H T) = 2\pi r\Delta r\rho V C_H T\big|_x - 2\pi r\Delta r\rho V C_H T\big|_{x+\Delta x}$$

$$-2\pi r\Delta x\Delta r h a(T-T_m)$$

0(negligibly small)

$$\varepsilon\frac{\partial(\rho C_H T)}{\partial t} = -\frac{\partial}{\partial x}(\rho V C_H T) - ha(T-T_m) \qquad (1)$$

where C_H = 0.24+0.46 H (kcal/^{o}C kg-dry air)

$$\rho = \frac{1}{V_H} = \frac{273}{(0.772+1.24H)(273+T)} \quad (\text{kg-dry air/m}^3)$$

V = constant throughout bed

V_H = humid volume (m^3/kg-dry air)

Air Humidity Balance

$$\varepsilon 2\pi r\Delta r\Delta x \frac{\partial}{\partial t}(H\rho) = 2\pi r\Delta r V\rho H\big|_{x} - 2\pi r\Delta r V\rho H\big|_{x+\Delta x} + 2\pi r\Delta r\Delta x\, k_H a(H_m^* - H)$$

0(negligible small)

$$\varepsilon \frac{\partial}{\partial t}(H\rho) = -\frac{\partial}{\partial x}(\rho V H) + k_H a(H_m^* - H) \qquad (2)$$

$$\text{where } H_m^* = fn(T_m)$$

Material Heat Balance:

$$2\pi r\Delta r\Delta x \frac{\partial}{\partial t}(\rho_b C_m T_m) = 2\pi r\Delta r\Delta x\, ha(T-T_m) - 2\pi r\Delta r\Delta x\, k_H a(H_m^* - H)\gamma_m$$

$$\rho_b \frac{\partial}{\partial t}(C_m T_m) = ha(T-T_m) - k_H a(H_m^* - H)\gamma_m \qquad (3)$$

$$\text{where } C_m = C_p + C_w C \quad (\text{kcal/kg-dry material}\,^{\circ}C)$$

$$\gamma_m = fn(T_m)$$

Material Moisture Balance:

$$2\pi r\Delta r\Delta x \frac{\partial}{\partial t}(\rho_b C) = -2\pi r\Delta r\Delta x\, k_H a(H_m^* - H)$$

$$\rho_b \frac{\partial C}{\partial t} = -k_H a\,(H_m^* - H) \qquad (4)$$

Overall Drying Rate

$$R = (\rho_{out} H_{out} - \rho_{in} H_{in})Va \quad (\text{kg.water/m}^3\text{-bed hr})$$

$$= \frac{1}{L}\int_{x=0}^{x=L} k_H a(H_m^* - H)\,dx$$

$$= \frac{1}{L}\int_{x=0}^{x=L} \rho_b\left(-\frac{\partial C}{\partial t}\right) dx$$

Average Moisture Content

$$W = \frac{1}{L}\int_0^L C\,dx$$

Boundary Conditions

$x = 0 \quad T = T_i$

$x = 0 \quad H = H_i$

Initial Conditions

$t = 0 \quad C = C_i$

$t = 0 \quad T_m = T_{mi}$

Coments

a. During constant drying rate period

$ha(T-T_m) = k_h a(H_m^* - H)\gamma_m$

Therefore, equation (3) becomes

$\rho_b \frac{\partial}{\partial t}(C_m T_m) = 0$

With $T_m = T_w$ (wet bulb temperature of air)

$= fn(T,H)$

Also $\gamma_m = \gamma_w$

$H_m^* = H_w^*$

b. During preheating or falling rate period,

$ha(T-T_m) > k_H a(H_m^* - H)\ \gamma_m$

c. Equations (1) ~(4) constitute the model for through-flow drying. Other relationships, such as $H_m^* = fn(T_m)$, $\gamma_m = fn(T_m)$, are also necessary.

d. To find what dimensionless groups (such as Re, Sc, Pr) ha and $k_H a$ depend upon, another type of dimensional analysis (similar to those in. Transport Phenomena) must be carried out. Though this is not done here, it can be expected that

$$ha = fn(Re, Pr, geometry, \varepsilon, H, Hm^*, \rho, Cm, t)$$

$$k_H a = fn(Re, Sc, geometry, \varepsilon, H, Hm^*, \rho_b, Cm, t)$$

VITA

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