Fundamentals of Ventilation - List of Equation

Basic principles

$$I = \frac{\dot{V}_o}{V_r}$$

$$I_S = \frac{\dot{V}_s}{V_r}$$

$$C\ [\text{ppm}] = C\ [\text{mg/m}^3]\,\frac{24,44}{M}$$

$$\dot{G} d\tau + \dot{V} c_s d\tau = \dot{V} c\ d\tau + V_r dc$$

$$\dot{V} = \frac{\dot{G}}{c - c_s} = \frac{\dot{G}}{PEL - c_s}$$

$$\dot{V} = \frac{\dot{Q}}{\rho c \left(t_i - t_s\right)}$$

$$\dot{V} = \frac{\dot{M}_w}{\rho \left(x_i - x_s\right)}$$

Thermal environment

$$q = q_m - w = \pm q_c \pm q_r + q_{ev} \pm q_{res} \underbrace{\pm q_{con}}_{0}$$

$$w = \eta \cdot q_m$$

$$PMV = f\left(t_a, MRT, w, RH, I_{cl}, q_m\right)$$

$$DR = f\left(t_a, MRT, Tu\right)$$

$$t_o = \frac{h_c t_a + h_r t_r}{h_c + h_r}$$

$$t_o = \frac{t_a + t_r}{2}$$ for $w < 0,2$ m/s

Psychrometrics

$$\varphi = \frac{p_v}{p_{v,s}}$$

$$x = 0.622 \frac{\varphi p_{v,s}}{p - \varphi p_{v,s}}$$

$$h = c_a t + x\left(l + c_v t\right) = 1.01t + x\left(2500 + 1.86t\right)$$

Mixing of two airflows

$$M_1 x_1 + M_2 x_2 = (M_1 + M_2) x_m$$

$$M_1 h_1 + M_2 h_2 = (M_1 + M_2) h_m$$

Heat exchangers

$$\dot{Q}_{hc} = \dot{V} \rho c \left(t_2 - t_1\right)$$
$$\dot{Q}_{cc} = \dot{Q}_{sen} + \dot{Q}_{lat} = \dot{V} \rho c \left(t_1 - t_2\right) + \dot{V} \rho l \left(x_1 - x_2\right) = \dot{V} \rho \left(h_1 - h_2\right)$$
$$\dot{Q}_{hum} = \dot{V} \rho l \left(x_1 - x_2\right)$$
$$\dot{M}_{w,hum} = \dot{V} \rho \left(x_1 - x_2\right)$$

Natural ventilation

$$\dot{M} = \frac{\dot{Q}}{c\left(t_{ex} - t_s\right)}$$

$$\Delta p = hg\left(\rho_o - \rho_i\right)$$

$$M_{ex} = M_s = M$$

$$\mu_{ex} A_{ex} \rho_{ex} w_{ex} = \mu_s A_s \rho_s w_s \quad \leftarrow \quad w_s = \sqrt{\frac{2\Delta p_s}{\rho_s}}; w_{ex} = \sqrt{\frac{2\Delta p_{ex}}{\rho_{ex}}}$$

$$\frac{\Delta p_s}{\Delta p_{ex}} = \frac{\mu_{ex}^2}{\mu_s^2} \frac{\rho_{ex}}{\rho_s} \frac{A_{ex}^2}{A_s^2}$$

$$\Delta p = \Delta p_s + \Delta p_{ex}$$

$$B = \frac{t_{oz} - t_o}{t_{ex} - t_o}$$

Mechanical ventilation

$$\dot{Q}_{hc} = \dot{Q}_{hl,vent} + \dot{Q}_{hl,tran} = \dot{V} \rho c \left(t_i - t_o\right) + \dot{V} \rho c \left(t_{sup} - t_i\right) = \dot{V} \rho c \left(t_{sup} - t_o\right)$$

$$\dot{Q}_{hl,tran} = UA\left(t_i - t_o\right)$$

Heat / moisture recovery

$$\Phi = \frac{t_{rec} - t_o}{t_i - t_o}$$

$$\Phi_{\min} = 73\%$$

$$\psi = \frac{x_{rec} - x_o}{x_i - x_o}$$

Duct design

$$\mathrm{Re} = \frac{wd}{\nu}$$

$$\frac{w_s}{w_{\max}} = 0{,}817$$

$$\Delta p \ = \lambda \frac{l}{d} \frac{w^2}{2} \rho + \sum \zeta \frac{w^2}{2} \rho = K \cdot \dot{V}^2$$

$$K = \left(\frac{\lambda \cdot l}{d} + \sum \zeta \right) \frac{8 \cdot \rho}{\pi^2 \cdot d^4}$$

$$\lambda = f\left(\mathrm{Re}, \varepsilon/d\right)$$

$\lambda \cong 0.02$ for galvanized steel

$$d_h = \frac{4A}{O} = \frac{4ab}{2(a+b)} = \frac{2ab}{a+b}$$

Fans

$$P = \frac{\dot{V} \Delta p}{\eta_{\text{tot}}}$$

$$SFP = \frac{P}{\dot{V}} = \frac{\Delta p}{\eta_{tot}}$$

$$E_{tot} = \int_0^\tau P d\tau = \sum_0^n P = \frac{\dot{V} \Delta p}{1000 \cdot \eta_{tot}} \tau = SFP \cdot \dot{V} \cdot \tau$$

$$\Delta p = p_{t2} - p_{t1} = \Delta p_{t1} + \Delta p_{t2} = \Delta p_{l1} + \Delta p_{l2} + p_{d2}$$

$$p_t = p_s + p_d$$

$$p_d = \frac{w^2}{2}\rho$$

Fan laws

$$\dot{V}_2 = \dot{V}_1 \frac{n_2}{n_1}$$

$$\Delta p_2 = \Delta p_1 \left(\frac{n_2}{n_1}\right)^2 \frac{\rho_2}{\rho_1}$$

$$P_2 = P_1 \left(\frac{n_2}{n_1}\right)^3 \frac{\rho_2}{\rho_1}$$