FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

Ventilation

8. Mechanical ventilation

Bachelor / Master degree course

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Mechanical ventilation

Ventilation system provides:

- supply of outdoor air
- filtration
- air heating
- exhaust of air
- separation of contaminants

Volume Air Flow Rate

a) according to indoor air quality

$$\dot{V} = \frac{\dot{G}}{c - c_{sup}}$$

- for $V_{ex} = V_{sup}$
- where $c \leq PEL$

or

$$\dot{V} = \frac{\dot{Q}}{\rho c \left(t_i - t_{sup} \right)} \qquad \dot{V} = \frac{\dot{M}_v}{\rho \left(x_i - x_{sup} \right)}$$

Volume Air Flow Rate

b) according to the hygienic requirements

$$\dot{V}_o = n \cdot D$$

c) according to the ventilation rate *I*

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

Note:
Nominal air exchange rate ≠ Space air exchange rate

Dimensioning of Ventilation - Winter

Dimensioning of the systems for ventilation and heating WINTER

Ventilation can use:

1) ventilation air only $V_{sup} = V_o$

2) outdoor + recirculation air $V_{sup} = V_o + V_{rec}$

Outdoor air is usually heated:

- supply air temperature t_{sup}
- heating coil capacity Q_{HC}

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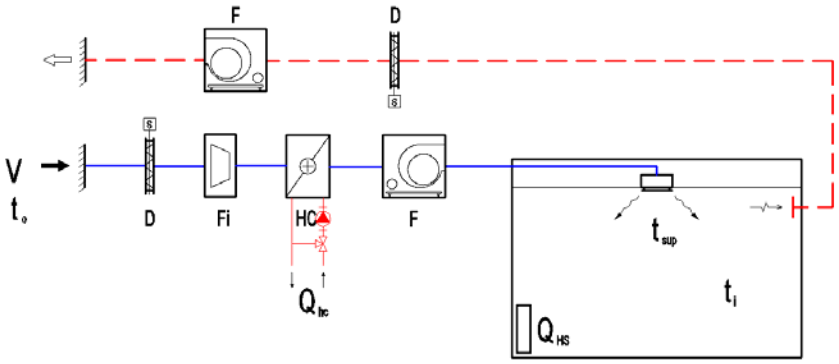
Dimensioning of Ventilation

1) Ventilation with outdoor air only
(no recirculation of the air)



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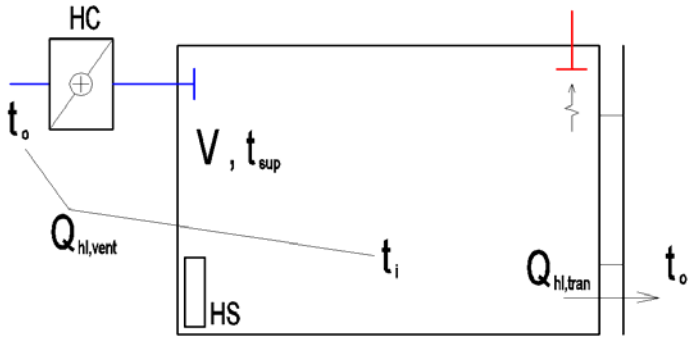
Heating coil capacity

Heating capacity covers (generally):

1) Ventilation heat loss
2) Transmission heat loss

$$\dot{Q}_{hc} = \dot{Q}_{hl,vent} + \dot{Q}_{hl,tran}$$

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



Dimensioning of Ventilation

Combination of heating and ventilation systems (no air recirculation)

a) **Ventilation only** - the transmission heat loss is covered by heating system
b) **Air heating (including ventilation)** – ventilation system covers the transmission heat loss (no heating system in the room is installed)
c) **Air heating + heating system** – ventilation system cover the transmission heat loss partially

Dimensioning of Ventilation

a) Ventilation only

- there is heating system (radiator) in the room to achieve indoor air temperature t_i
- supply air temperature $t_{sup} = t_i$
- heating coil capacity

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

where t_o = – 15 °C in Prague

Dimensioning of Ventilation

b) Air heating

Ventilation system covers the transmission heat loss (no heating system in the room is installed)

- no radiator in the room
- supply air temperature t_{sup}

$$t_{sup} = \frac{\dot{Q}_{hl,tran}}{\dot{V}\rho c} + t_i$$

- heating coil capacity

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

Dimensioning of Ventilation

Supply air/Room air temp. difference

$$\Delta t = \left| t_i - t_{sup} \right|$$

It depends od the space air diffusion (distribution of the supply air)

- WINTER $\Delta t \leq$ 15 - 25 K
- SUMMER Δt = 3 K - displacement vent.
  6 to 10 K - mixed systems (grilles)
  to 12 K - swirl diffusers

Dimensioning of Ventilation

c) Air heating (including ventilation) + heating system

Ventilation system covers the transmission heat loss partially

- heating system in the room covers only one part of total transmission heat loss to achieve the room air temperature $t_{i,hs}$ (e.g. 10 to 15 °C in the night, weekdays, …)
- the second part of heating loss is covered by ventilation system during the working time

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

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

Dimensioning of Ventilation

- heating system

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

- ventilation system

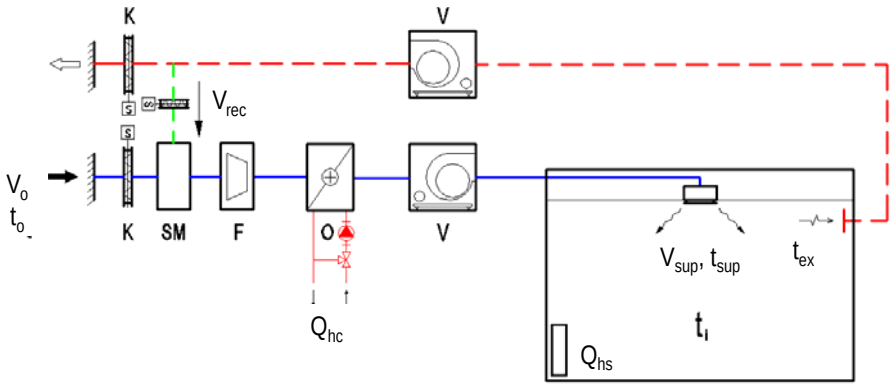
$$\dot{Q}_{hl,tran,vs} = \dot{Q}_{hl,tran} - \dot{Q}_{hl,tran,hs} = \dot{Q}_{hl,tran}\left(1 - \frac{t_{i,hs} - t_o}{t_i - t_o}\right)$$

- heating coil capacity

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

Dimensioning of Ventilation

2) Ventilation with recirculation



Dimensioning of Ventilation

The reasons for recirculation air using:

- supply air/room air temp. difference $(t_{sup} - t_i) > 25$ K
- decreasing of energy consumption

$$\dot{V}_{sup} = \dot{V}_o + \dot{V}_{rec}$$

- if $t_{rec} = t_i$

$$t_{sup} = \frac{\dot{Q}_{hl,tran}}{\dot{V}_{sup}\rho c} + t_i$$

Dimensioning of Ventilation

Note:

If $t_{rec} \neq t_i$, then

- when $t_{rec} < t_i$ → $+ Q_{rec}$
- when $t_{rec} > t_i$ → $- Q_{rec}$

- heating coil capacity

$$\dot{Q}_{HC} = \dot{V}_{sup}\rho c\left(t_{sup} - t_m\right)$$

$$t_m = \frac{\dot{M}_{rec}t_{rec} + \dot{M}_o t_o}{\dot{M}_{rec} + \dot{M}_o}$$

Dimensioning of Ventilation

Dimensioning of the systems for ventilation and heating
SUMMER

- the outdoor air only
- the supply air = outdoor air

$$t_{sup} = t_o$$

- no recirculation (the temperature of indoor air is usually higher then outdoor air temperature)

Dimensioning of Ventilation - Summer

Volume air flow rate V_o determination:
a) according to indoor air quality

$$\dot{V}_{o1} = \frac{\dot{G}}{PEL - c_{sup}}$$

b) according to cooling load

$$\dot{V}_{o2} = \frac{\dot{Q}_{cl,i}}{\rho c \left(t_i - t_o\right)}$$

$$\dot{V}_o = \max(\dot{V}_{o1}, \dot{V}_{o2})$$

Dimensioning of Heating coil

Example 1:
Conference hall for 50 people - V_0 = 25 m^3/h.person (ρ = 1,2 kg/m^3)
Transmission heat loss $Q_{hl,tran}$ = 8,4 kW
Indoor air temparature t_i = 20 °C
Outdoor air temperature t_o = -15 °C

Calculate heating coil capacity Q_{hc} for all cases:
a) Ventilation only
b) Air heating
supply air/room air temp. difference ($t_{sup} - t_i$) = 20 K
c) Air heating + heating system
$t_{i,hs}$ = 10 °C

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Using recirculation

Example 2:
Cinema for 100 people
Air flow rate: V_0 = 25 m^3/h.person (ρ = 1,2 kg/m^3)
Transmission heat loss: $Q_{hl,tran}$ = 20 kW
Indoor air temparature: t_i = 20 °C
Outdoor air temperature: t_o = -15 °C

Calculate heating coil capacity Q_{hc} for 1 case:
b) Ventilation and air heating – ventilation system covers the heating load
- supply air/room air temp. difference ($t_{sup} - t_i$) = 15 K

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Air heating of family house

Example 3:

Family house with floor area 150 m^2, height of the room 2,6 m
Heating load Q = 4,2 kW
Ventilation rate I = 0,5 h^{-1}
Outdoor air temperature t_o = -15 °C
Heat recovery coefficient Φ = 65 %.

Calculate the air flow rate to cover heating load, if supply air/room air temp. difference $\Delta t = (t_{sup} - t_i)$ = 25 K.

Calculate the ratio between outdoor air and recirculation air.

Calculate heating coil capacity Q_{HC}

Thank you for your attention