FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

Environmental Engineering

6. Air-conditioning; Dimensioning of CAV system

Bachelor degree course

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Winter semester 11/2023

Air-conditioning

Air-conditioning systems

Heat Transfer
- convective
- radiant

Number of zones
- one - zone
- multizone

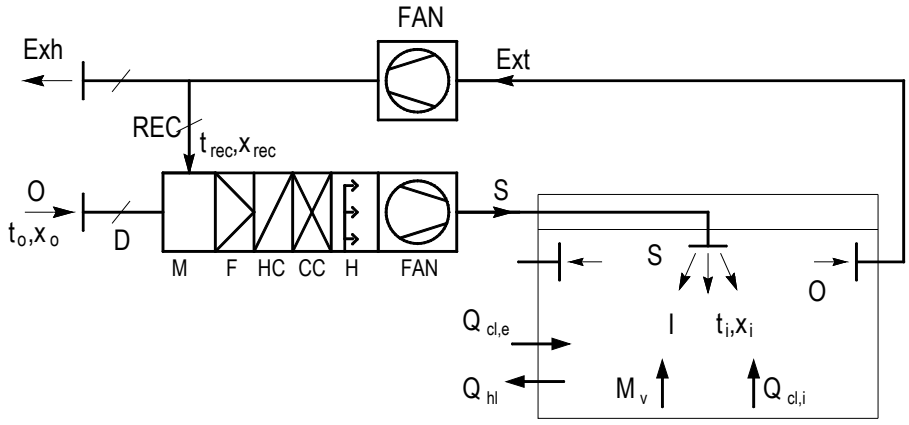
Purpose
- comfort
- technology
- biology
- safety

Medium

- air	→ single-duct, dual-duct
- water	→ cooled ceilings, fan coil units
- air + water	→ induction units (chilled beams)
- refrigerant	→ split, multisplit, VRV

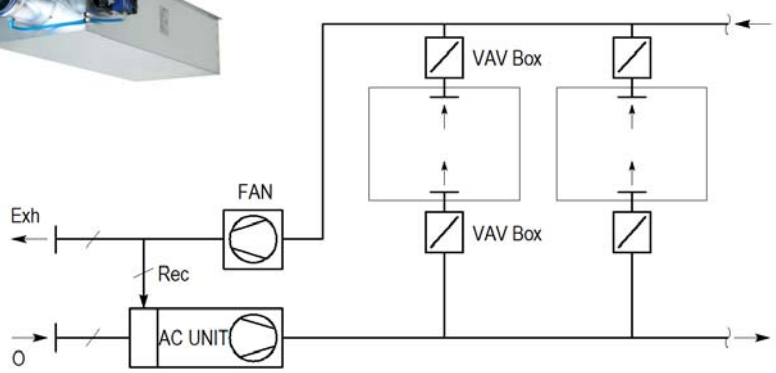
Air-conditioning

Single-duct air system with constant air flow rate
CAV system



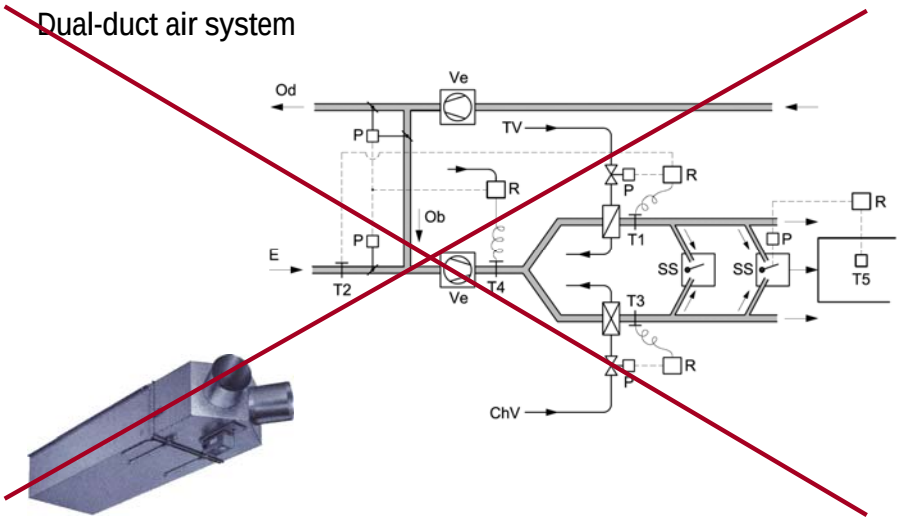
Air-conditioning

Single-duct air system with variable volume air flow rate
VAV system



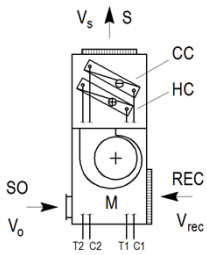
Air-conditioning

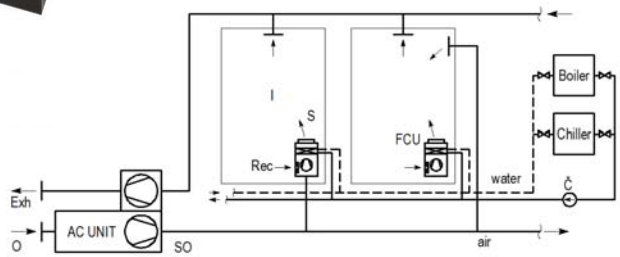
Dual-duct air system



Air-conditioning

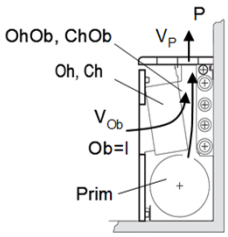
Fan-coil unit system

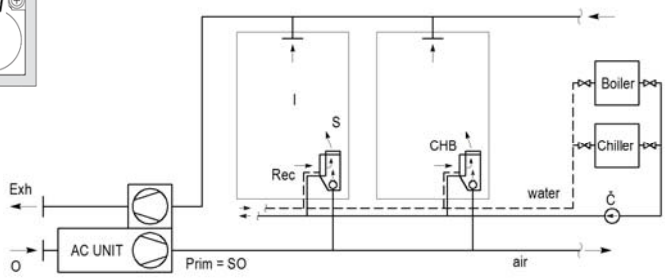




Air-conditioning

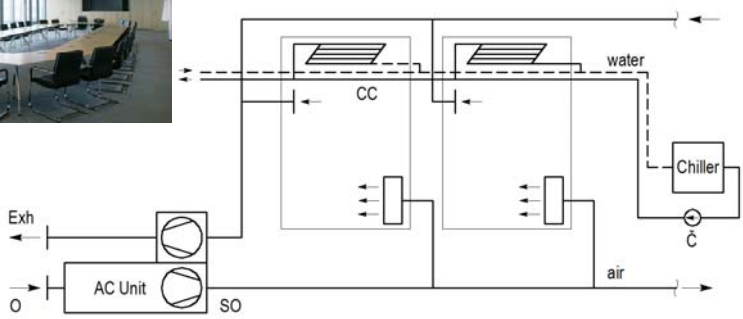
Induction unit, Chilled beams system





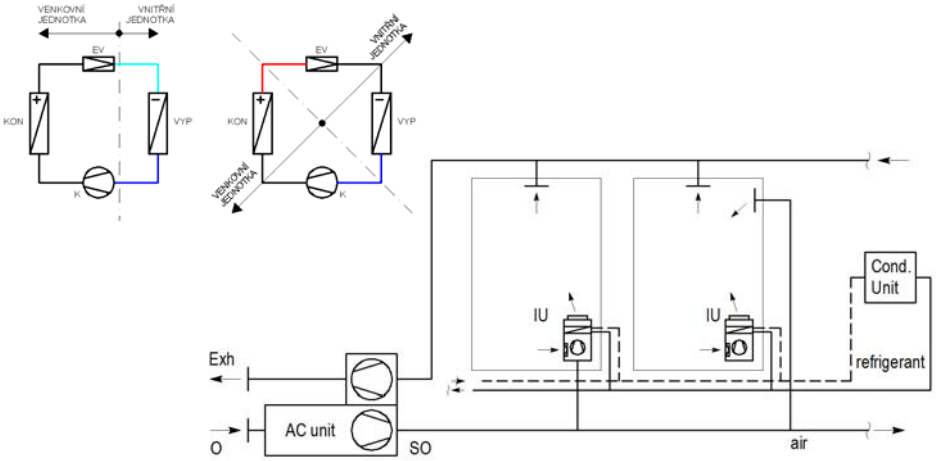
Air-conditioning

Cooled ceiling system



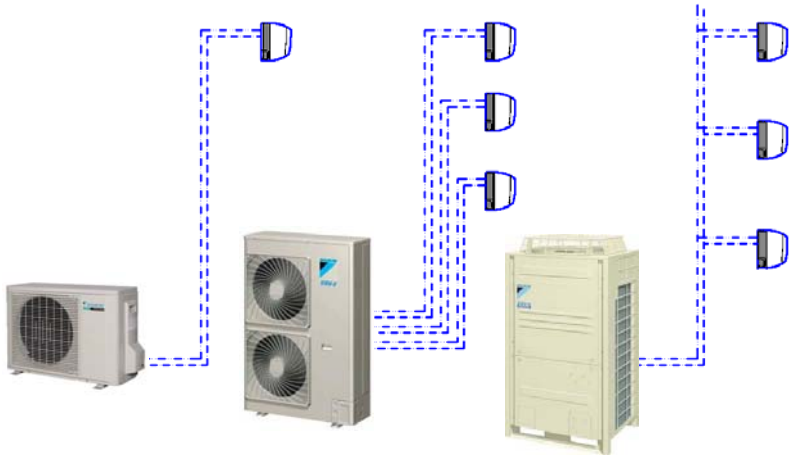
Air-conditioning

Refrigerant systems



Air-conditioning

Split Multi-split VRV



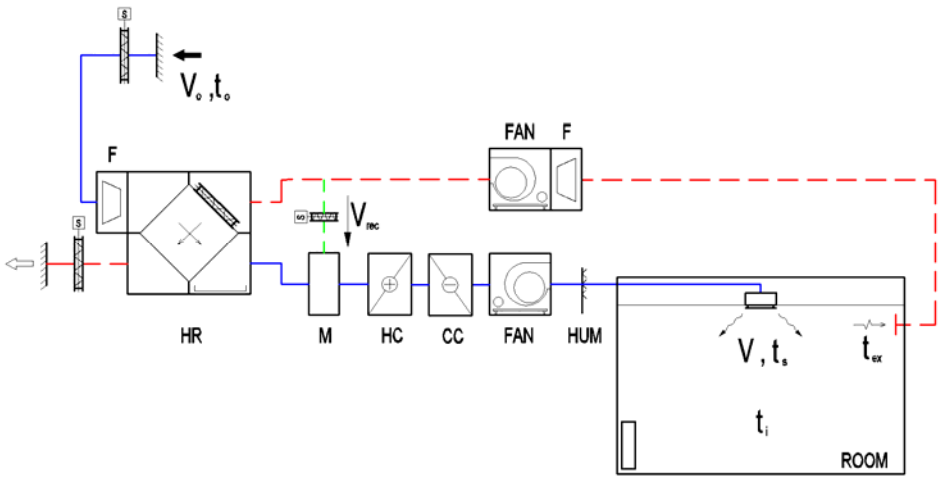
FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

Dimensioning of CAV system

Single duct air system with constant air flow rate (one – zone)

CAV system



Input data

Heat loss and Cooling load

- sensible cooling load Q_{cl}
- sensible heating load Q_{hl}

Outdoor air parameters – extreme weather conditions

Prague:

$t_{o,win}$ = – 15 °C φ_o = 100 %

$t_{o,sum}$ = 32 °C h_o = 58 kJ/kg

Input data

Indoor air parameters

$t_{i,win}$ = 20 ÷ 22 °C φ_i = 30 ÷ 70 %

$t_{i,sum}$ = 25 ÷ 27 °C φ_i = 30 ÷ 70 %

Ventilation requirements

- for the people – from 25 to 90 m^3/h per person
- for technology – according to mass balance of contaminants

Heating coil and cooling coil parameters

- water heating 80/60 °C, …
- water cooling 6/12 °C, … $t_c = t_{m,w}$ = (6 + 12)/2 = 9 °C
- evaporator t_c = 4 ÷ 5 °C

Input data

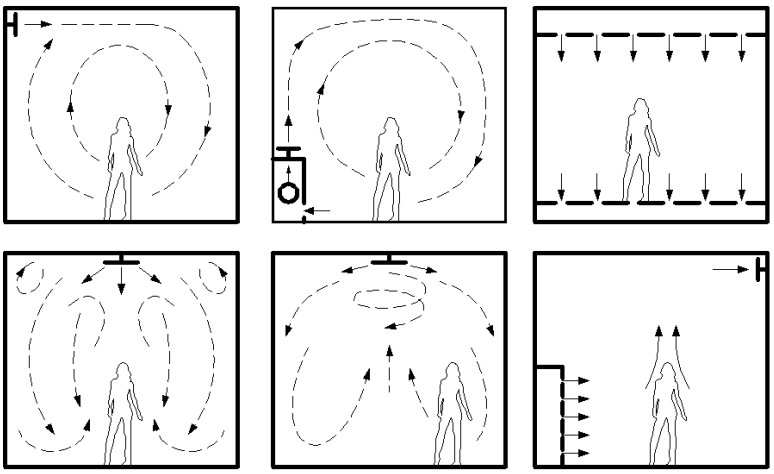
Supply air/Room air temp. difference

$$\Delta t = |t_i - t_s|$$

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

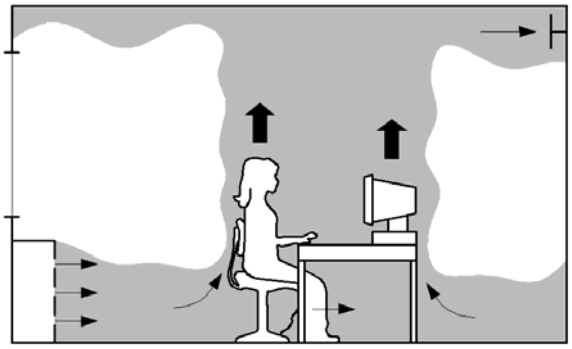
- WINTER $\Delta t \leq 15$ (25) K
- SUMMER
  - 3 to 5 K - displacement vent.
  - 6 to 10 K - mixing systems (grilles)
  - up to 12 K - swirl diffusers

Space air diffusion



Space air diffusion

Displacement ventilation



Dimensioning of Ventilation

SUMMER process

1) Volume air flow rate

- hygienic requirements $\rightarrow V_o$

$V_o = n.R$ = number of person x vent. requirements [m^3/h]

- sensible cooling load $\rightarrow V$

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

- if $V > V_o$ than the recirculation air is used $\rightarrow V_{rec}$

$$\dot{V}_{rec} = \dot{V} - \dot{V}_o$$

Dimensioning of Ventilation

2) h-x diagram

E: $t_{o,sum}$ = 32 °C; $h_{o,sum}$ = 58 kJ/kg

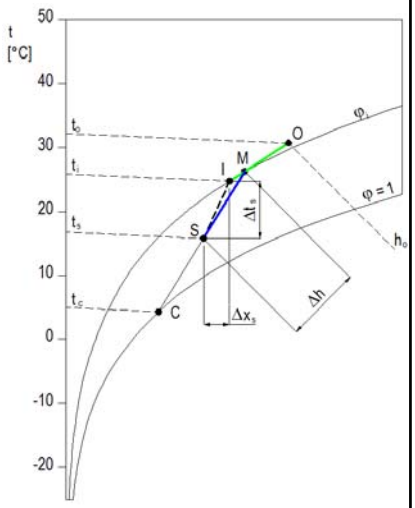
I: t_i = 25 °C

φ_i = 30 až 50 % (approx.)

M: mixing V_{circ}/V_o

CC: t_c (according to cooling coil type)

S: MC x t_s



Dimensioning of Ventilation

3) Humidification in the room

$$\dot{M}_v = n.\dot{M}_{v1}$$ … production of people water vapor

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

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

$$\left(x_i - x_s\right)_{calc} \overset{!}{=} \left(x_i - x_s\right)_{h-x}$$

… if not → move the position of state I on isotherm t_i

Dimensioning of Ventilation

4) Cooling coil capacity

$$\dot{Q}_{sen} = \dot{V}\rho c\left(t_m - t_s\right)$$

$$\dot{Q}_{lat} = \dot{V}\rho l\left(x_m - x_s\right)$$

$$\dot{Q}_{cc} = \dot{Q}_{sen} + \dot{Q}_{lat} = \dot{V}\rho\left(h_m - h_s\right)$$

Množství vodní páry, která zkondenzuje na povrchu chladiče

$$\dot{M}_v = \dot{V}\rho\left(x_m - x_s\right)$$

Dimensioning of Ventilation

WINTER process

1) Temperature of supply air

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

$$\left(t_s - t_i\right) \leq 15(25) \qquad [K]$$

… if the heating system cover the heating load

… if not Δt = 0 K

Dimensioning of Ventilation

2) h-x diagram

O: $t_{o,win} = t_{o,calc} - 3$ °C

$\varphi_o = 100$ %

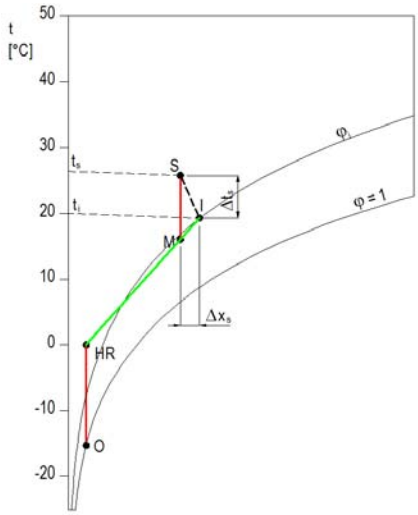
I: $t_i = 20$ °C

$\varphi_i = 30$ až 50 % (approx.)

HR: $t_{HR} \leftarrow$ efficiency of heat recovery

M: mixing V_{circ}/V_o

S: air heating to t_s

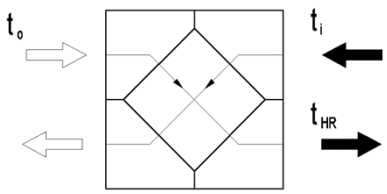


Dimensioning of Ventilation

3) Heat recovery

- reuse of the sensible heat from the air leaving the room (zone, building) and trasfer heat into the supply (outdoor) air
- heat recovery efficiency

$$\Phi = \frac{t_{HR} - t_o}{t_i - t_o} \rightarrow t_{HR} = \ldots$$



Dimensioning of Ventilation

4) Humidification in the room

- see summer process

5) Heating coil capacity

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

$$\dot{Q}_{hc} = \dot{V}\rho c\left(t_s - t_i\right) + \dot{V}\rho c\left(t_i - t_m\right)$$

$$\dot{Q}_{hc} = \dot{V}\rho c\left(t_s - t_m\right)$$

Dimensioning of Ventilation

WINTER process with steam humidification

h-x diagram

O: input

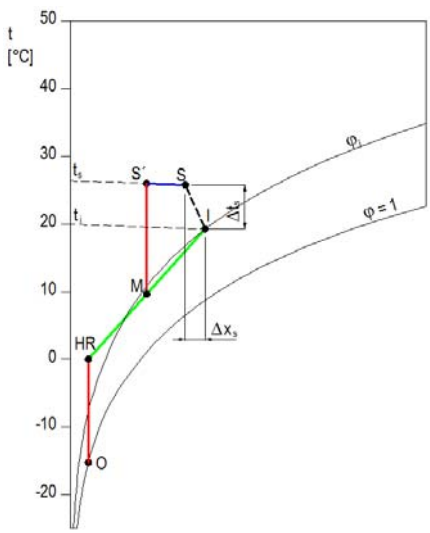
I: input

HR: heat recovery

M: mixing

S´: heating to t_s

S: humidification to x_s

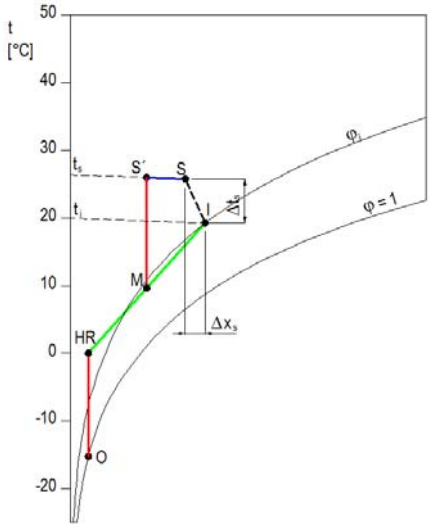


Dimensioning of Ventilation

6) Humidifier capacity

$$\dot{M}_{hum} = \dot{V}\rho\left(x_s - x_{s'}\right) \text{ [kg/s]}$$

$$\dot{Q}_{hum} = \dot{M}_{hum} l \quad \text{[W]}$$



Example: Single duct air system

Example 1: Dimensioning of single duct air system

	Summer	Winter
Cooling/Heating load	33.6 kW	25 kW
Occupancy	200 person	
Supply and room air temp. difference	10 K	-
Ventilation requirements	25 m^3/h person	
Temp. of indoor air	26 °C	20 °C
RH of indoor air	30 to 70 %	30 to 70 %
Outdoor air conditions	32 °C; 58 kJ/kg	-15 °C, 100 %
Water vapor person production	116 g/h	70 g/h
Cooling coil temperature	9 °C	-
Heat recovery efficiency	-	67 %

V_o = ?, V = ?, V_c = ?; Q_{hc} = ?; Q_{cc} = ?, Q_h = ? Draw h-x diagram

FAKULTA STROJNÍ ČVUT V PRAZE

ÚSTAV TECHNIKY PROSTŘEDÍ

Thank you for your attention

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