Equations

0. Reference data:

$$\dot{M}_{min} = 0.0001 \ \text{[kg/s]} \tag{1}$$

$$J/kg_{min} = 0.01 \ \text{[J/kg]} \tag{2}$$

$$Watt/Kelvin_{min} = 1 \ \text{[W/K]} \tag{3}$$

$p_{w,sat}$/Pascal=exp(A*((t/Celsius)/(B+(t/Celsius))+C)

$$A = 17.438 \ \square \tag{4}$$

$$B = 239.78 \ \square \tag{5}$$

$$C = 6.4147 \ \square \tag{6}$$

$$percent = 100 \ \text{[\%]} \tag{7}$$

$$g/kg = 1000 \ \text{[g/kg]} \tag{8}$$

$$Pascal = 1 \ \text{[pa]} \tag{9}$$

$$Pa/mbar = 100 \ \text{[Pa/mbar]} \tag{10}$$

$$Celsius = 1 \ \text{[C]} \tag{11}$$

$$Watt = 1 \ \text{[W]} \tag{12}$$

$$Watt/kWatt = 1000 \ \text{[W/kW]} \tag{13}$$

$$kg/ms = 1 \ \text{[kg/m}\cdot\text{s]} \tag{14}$$

$$J/kg = 1 \ \text{[J/kg]} \tag{15}$$

$$h = 1 \ \text{[h]} \tag{16}$$

$$d = 1 \ \text{[day]} \tag{17}$$

$$w = 1 \ \text{[week]} \tag{18}$$

$$s/h = 3600 \ \text{[s/h]} \tag{19}$$

$$hour/day = 24 \ \text{[h/day]} \tag{20}$$

$$day/week = 7 \ \text{[day/week]} \tag{21}$$

$$J/kWh = 3.6 \times 10^6 \ \text{[J/kWh]} \tag{22}$$

Specific heats:

Liquid water:

$$c_f = 4187 \ \text{[J/kg}\cdot\text{K]} \tag{23}$$

Air:

$$c_{p,a} = 1005 \ [\mathrm{J/kg \cdot K}] \tag{24}$$

Water vapor:

$$c_{p,g} = 1820 \ [\mathrm{J/kg \cdot K}] \tag{25}$$

air constant:

$$r_a = 287 \ [\mathrm{J/kg \cdot K}] \tag{26}$$

Latent heat:

$$h_{fg,0} = 2.501 \times 10^6 \ [\mathrm{J/kg}] \tag{27}$$

Specific volume:

water:

$$v_f = 1 \times 10^{-3} \ \left[\mathrm{m^3/kg}\right] \tag{28}$$

air:

v_{ref}=287*(t_{ref}+273)*(1+1.6078*ω_{ref})/p_{ref}

$$v_{ref} = 0.8366 \ \left[\mathrm{m^3/kg}\right] \tag{29}$$

Molar mass:

$$MM_{dryair} = 28.86 \ [\mathrm{kg/kmol}] \tag{30}$$

$$MM_{CO2} = 44 \ [\mathrm{kg/kmol}] \tag{31}$$

Humidity ratio:

$$\omega_{ref} = 0.005 \ [\cdot] \tag{32}$$

Static pressure of reference:

$$p_{ref} = 101325 \ [\mathrm{Pa}] \tag{33}$$

Temperature of reference:

$$t_{ref} = 20 \ [\mathrm{C}] \tag{34}$$

Regressions:

wet bulb temperature:

T_{wb}=-4.99380809 + 0.000611112852*h - 3.67604205E-09*h^2 + 1.07152157E-14*h^3

T_{wb}/Celsius=C0 + C1*h/J \kg +C2*(h/J \kg)^2 + C3*(h/J \kg)^3

$$C0 = -4.99380809 \tag{35}$$

$$C1 = 0.000611112852 \tag{36}$$

$$C2 = -3.67604205 \times 10^{-9} \tag{37}$$

$$C3 = 1.07152157 \times 10^{-14} \tag{38}$$

Humidity ratio at saturation:

ω=0.00538248677 - 0.00000552571908*T + 0.000023594148*T^2

ω=D0+D1*T/Celsius + D2*(T/Celsius)^2

$$D0 = 0.00538248677 \tag{39}$$

$$D1 = -0.00000552571908 \tag{40}$$

$$D2 = 0.000023594148 \tag{41}$$

T/Celsius=-5.10318967 + 2321.76298*ω - 41384.2716*omega^2

T/Celsius=E1 + E2*ω +E3*omega^2

$$E1 = -5.10318967 \tag{42}$$

$$E2 = 2321.76298 \tag{43}$$

$$E3 = -41384.2716 \tag{44}$$

(NB: these polynomial laws are only valid at normal atmospheric pressure)

`$BOOKMARK 01. BUILDING ZONE MODEL`

1. BUILDING ZONE MODEL

with distinction between the whole room and the occupancy zone!

$$n_{floor} = 10\ [\cdot] \tag{45}$$

1.1 Infiltration, exfiltration, ventilation flow rates and room air mass balances:

1.1.1 Infiltration and exfiltration flow rates:

Volumes:

$$V_{in,01} = V_1 \tag{46}$$

$$V_{in,02} = V_2 \tag{47}$$

$$V_{in,03} = V_3 \tag{48}$$

$$V_{in,04} = V_4 \tag{49}$$

$$V_{in,05} = V_5 \tag{50}$$

$$V_{in,06} = V_6 \tag{51}$$

Maximal infitration air renewals:

$$n_{infiltr,max,01} = 0.2\ [1/\text{h}] \tag{52}$$

$$n_{infiltr,max,02} = 0.2 \ [1/\text{h}] \tag{53}$$

$$n_{infiltr,max,03} = 0.2 \ [1/\text{h}] \tag{54}$$

$$n_{infiltr,max,04} = 0.2 \ [1/\text{h}] \tag{55}$$

$$n_{infiltr,max,05} = 0 \ [1/\text{h}] \tag{56}$$

$$n_{infiltr,max,06} = 0 \ [1/\text{h}] \tag{57}$$

$$f_{infiltr,01} = 1 \tag{58}$$

$$f_{infiltr,02} = 1 \tag{59}$$

$$f_{infiltr,03} = 1 \tag{60}$$

$$f_{infiltr,04} = 1 \tag{61}$$

$$f_{infiltr,05} = 0 \tag{62}$$

$$f_{infiltr,06} = 0 \tag{63}$$

(no infiltration in the central zone, neither in the ceiling void)

(Supposed to be) actual infiltration flow rates:

$$\dot{M}_{a,infiltr,01} = f_{infiltr,01} \cdot \dot{M}_{a,infiltr,max,01} \tag{64}$$

$$\dot{M}_{a,infiltr,max,01} = \dot{V}_{a,infiltr,max,01}/v_a \tag{65}$$

$$\dot{V}_{a,infiltr,max,01} = \dot{V}_{a,infiltr,max,m3h,01}/s/h \tag{66}$$

$$\dot{V}_{a,infiltr,max,m3h,01} = n_{infiltr,max,01} \cdot V_{in,01} \tag{67}$$

$$\dot{M}_{a,infiltr,02} = f_{infiltr,02} \cdot \dot{M}_{a,infiltr,max,02} \tag{68}$$

$$\dot{M}_{a,infiltr,max,02} = \dot{V}_{a,infiltr,max,02}/v_a \tag{69}$$

$$\dot{V}_{a,infiltr,max,02} = \dot{V}_{a,infiltr,max,m3h,02}/s/h \tag{70}$$

$$\dot{V}_{a,infiltr,max,m3h,02} = n_{infiltr,max,02} \cdot V_{in,02} \tag{71}$$

$$\dot{M}_{a,infiltr,03} = f_{infiltr,03} \cdot \dot{M}_{a,infiltr,max,03} \tag{72}$$

$$\dot{M}_{a,infiltr,max,03} = \dot{V}_{a,infiltr,max,03}/v_a \tag{73}$$

$$\dot{V}_{a,infiltr,max,03} = \dot{V}_{a,infiltr,max,m3h,03}/s/h \tag{74}$$

$$\dot{V}_{a,infiltr,max,m3h,03} = n_{infiltr,max,03} \cdot V_{in,03} \tag{75}$$

$$\dot{M}_{a,infiltr,04} = f_{infiltr,04} \cdot \dot{M}_{a,infiltr,max,04} \tag{76}$$

$$\dot{M}_{a,infiltr,max,04} = \dot{V}_{a,infiltr,max,04}/v_a \tag{77}$$

$$\dot{V}_{a,infiltr,max,04} = \dot{V}_{a,infiltr,max,m3h,04}/s/h \tag{78}$$

$$\dot{V}_{a,infiltr,max,m3h,04} = n_{infiltr,max,04} \cdot V_{in,04} \tag{79}$$

$$\dot{M}_{a,infiltr,05} = f_{infiltr,05} \cdot \dot{M}_{a,infiltr,max,05} \tag{80}$$

$$\dot{M}_{a,infiltr,max,05} = \dot{V}_{a,infiltr,max,05}/v_a \tag{81}$$

$$\dot{V}_{a,infiltr,max,05} = \dot{V}_{a,infiltr,max,m3h,05}/s/h \tag{82}$$

$$\dot{V}_{a,infiltr,max,m3h,05} = n_{infiltr,max,05} \cdot V_{in,05} \tag{83}$$

with

$$v_a = v_{ref} \tag{84}$$

in fair approximation

1.1.2 Ventilation flow rates (supposed to be imposed by ventilation terminals):

1.1.2.1 Sizing of the ventilation system (nominal flow rates):

$$\dot{M}_{a,ventilation,01,n} = \dot{V}_{a,ventilation,01,n}/v_a \tag{85}$$

$$\dot{V}_{a,ventilation,01,n} = \dot{V}_{a,ventilation,01,m3h,n}/s/h \tag{86}$$

$$\dot{V}_{a,ventilation,01,m3h,n} = \dot{V}_{a,m3/hoccupant,01,n} \cdot n_{occ,max,01} \tag{87}$$

$$\dot{V}_{a,m3/hoccupant,01,n} = 36 \ \left[\mathrm{m^3/h}\right] \tag{88}$$

$$\dot{M}_{a,ventilation,02,n} = \dot{V}_{a,ventilation,02,n}/v_a \tag{89}$$

$$\dot{V}_{a,ventilation,02,n} = \dot{V}_{a,ventilation,02,m3h,n}/s/h \tag{90}$$

$$\dot{V}_{a,ventilation,02,m3h,n} = \dot{V}_{a,m3/hoccupant,02,n} \cdot n_{occ,max,02} \tag{91}$$

$$\dot{V}_{a,m3/hoccupant,02,n} = 36 \ \left[\mathrm{m^3/h}\right] \tag{92}$$

$$\dot{M}_{a,ventilation,03,n} = \dot{V}_{a,ventilation,03,n}/v_a \tag{93}$$

$$\dot{V}_{a,ventilation,03,n} = \dot{V}_{a,ventilation,03,m3h,n}/s/h \tag{94}$$

$$\dot{V}_{a,ventilation,03,m3h,n} = \dot{V}_{a,m3/hoccupant,03,n} \cdot n_{occ,max,03} \tag{95}$$

$$\dot{V}_{a,m3/hoccupant,03,n} = 36 \ \left[\mathrm{m^3/h}\right] \tag{96}$$

$$\dot{M}_{a,ventilation,04,n} = \dot{V}_{a,ventilation,04,n}/v_a \tag{97}$$

$$\dot{V}_{a,ventilation,04,n} = \dot{V}_{a,ventilation,04,m3h,n}/s/h \tag{98}$$

$$\dot{V}_{a,ventilation,04,m3h,n} = \dot{V}_{a,m3/hoccupant,04,n} \cdot n_{occ,max,04} \tag{99}$$

$$\dot{V}_{a,m3/hoccupant,04,n} = 36 \ \left[\mathrm{m^3/h}\right] \tag{100}$$

$$\dot{M}_{a,ventilation,05,n} = \dot{V}_{a,ventilation,05,n}/v_a \tag{101}$$

$$\dot{V}_{a,ventilation,05,n} = \dot{V}_{a,ventilation,05,m3h,n}/s/h \tag{102}$$

$$\dot{V}_{a,ventilation,05,m3h,n} = \dot{V}_{a,m3/hoccupant,05,n} \cdot n_{occ,max,05} \tag{103}$$

$$\dot{V}_{a,m3/hoccupant,05,n} = 36 \ \left[\mathrm{m^3/h}\right] \tag{104}$$

1.1.2.2 Actual ventilation flow rates:

$$\dot{M}_{a,ventilation,01} = f_{ventilation,01} \cdot \dot{M}_{a,ventilation,01,n} \quad (105)$$

$$\dot{M}_{a,ventilation,02} = f_{ventilation,02} \cdot \dot{M}_{a,ventilation,02,n} \quad (106)$$

$$\dot{M}_{a,ventilation,03} = f_{ventilation,03} \cdot \dot{M}_{a,ventilation,03,n} \quad (107)$$

$$\dot{M}_{a,ventilation,04} = f_{ventilation,04} \cdot \dot{M}_{a,ventilation,04,n} \quad (108)$$

$$\dot{M}_{a,ventilation,05} = f_{ventilation,05} \cdot \dot{M}_{a,ventilation,05,n} \quad (109)$$

with factors f$_{ventilation,0j}$ given in §10

1.1.3 Rooms air mass balances:

$$\dot{M}_{a,room,01} = \dot{M}_{a,returnduct,su,01} + \dot{M}_{a,exfiltr,01} \quad (110)$$

$$\dot{M}_{a,room,01} = \dot{M}_{a,supplyduct,ex,01} + \dot{M}_{a,infiltr,01} \quad (111)$$

$$\dot{M}_{a,room,02} = \dot{M}_{a,returnduct,su,02} + \dot{M}_{a,exfiltr,02} \quad (112)$$

$$\dot{M}_{a,room,02} = \dot{M}_{a,supplyduct,ex,02} + \dot{M}_{a,infiltr,02} \quad (113)$$

$$\dot{M}_{a,room,03} = \dot{M}_{a,returnduct,su,03} + \dot{M}_{a,exfiltr,03} \quad (114)$$

$$\dot{M}_{a,room,03} = \dot{M}_{a,supplyduct,ex,03} + \dot{M}_{a,infiltr,03} \quad (115)$$

$$\dot{M}_{a,room,04} = \dot{M}_{a,returnduct,su,04} + \dot{M}_{a,exfiltr,04} \quad (116)$$

$$\dot{M}_{a,room,04} = \dot{M}_{a,supplyduct,ex,04} + \dot{M}_{a,infiltr,04} \quad (117)$$

$$\dot{M}_{a,room,05} = \dot{M}_{a,returnduct,su,05} + \dot{M}_{a,exfiltr,05} \quad (118)$$

$$\dot{M}_{a,room,05} = \dot{M}_{a,supplyduct,ex,05} + \dot{M}_{a,infiltr,05} \quad (119)$$

(whatever could be the over or under-pressure inside the room)

and, with equilibrated hygienic ventilation and without economizer,

$$\dot{M}_{a,supplyduct,ex,01} = \dot{M}_{a,ventilation,01} \quad (120)$$

$$\dot{M}_{a,returnduct,su,01} = \dot{M}_{a,supplyduct,ex,01} \quad (121)$$

$$\dot{M}_{a,supplyduct,ex,02} = \dot{M}_{a,ventilation,02} \quad (122)$$

$$\dot{M}_{a,returnduct,su,02} = \dot{M}_{a,supplyduct,ex,02} \quad (123)$$

$$\dot{M}_{a,supplyduct,ex,03} = \dot{M}_{a,ventilation,03} \quad (124)$$

$$\dot{M}_{a,returnduct,su,03} = \dot{M}_{a,supplyduct,ex,03} \quad (125)$$

$$\dot{M}_{a,supplyduct,ex,04} = \dot{M}_{a,ventilation,04} \quad (126)$$

$$\dot{M}_{a,returnduct,su,04} = \dot{M}_{a,supplyduct,ex,04} \quad (127)$$

$$\dot{M}_{a,supplyduct,ex,05} = \dot{M}_{a,ventilation,05} \quad (128)$$

$$\dot{M}_{a,returnduct,su,05} = \dot{M}_{a,supplyduct,ex,05} \quad (129)$$

1.2 Zone air mass balance:

Mixing effectiveness:

$$\epsilon_{ventmix,01} = 1 \ [\cdot] \quad (130)$$

$$\epsilon_{ventmix,02} = 1 \ [\cdot] \quad (131)$$

$$\epsilon_{ventmix,03} = 1 \ [\cdot] \quad (132)$$

$$\epsilon_{ventmix,04} = 1 \ [\cdot] \quad (133)$$

$$\epsilon_{ventmix,05} = 1 \ [\cdot] \quad (134)$$

(this term can be smaller in case of short-circuit)

$$\dot{M}_{a,zone,01} = \epsilon_{ventmix,01} \cdot \dot{M}_{a,room,01} \quad (135)$$

$$\dot{M}_{a,zone,02} = \epsilon_{ventmix,02} \cdot \dot{M}_{a,room,02} \quad (136)$$

$$\dot{M}_{a,zone,03} = \epsilon_{ventmix,03} \cdot \dot{M}_{a,room,03} \quad (137)$$

$$\dot{M}_{a,zone,04} = \epsilon_{ventmix,04} \cdot \dot{M}_{a,room,04} \quad (138)$$

$$\dot{M}_{a,zone,05} = \epsilon_{ventmix,05} \cdot \dot{M}_{a,room,05} \quad (139)$$

1.3 Zone sensible heat balance:

1.3.1 Zone internal energy storage model:

Output:

$t_{a,in,0j}$

Inputs:

Initial indoor temperatures:

$$t_{a,in,01,1} = t_0 \quad (140)$$

$$t_{a,in,02,1} = t_0 \quad (141)$$

$$t_{a,in,03,1} = t_0 \quad (142)$$

$$t_{a,in,04,1} = t_0 \quad (143)$$

$$t_{a,in,05,1} = t_0 \quad (144)$$

$$t_{a,in,06,1} = t_0 \quad (145)$$

transient heat flow rate: see §1.3.6

Parameters:

$V_{in,0j}$

Indoor capacity factor:

$$ICF = 5 \tag{146}$$

$\tau_1, \tau_2, \Delta\tau$: see§11.

Simulation model:

$$\Delta U_{in,01} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,01} \, \mathrm{d}\tau \tag{147}$$

$$\Delta U_{in,kWh,01} = \frac{\Delta U_{in,01}}{J/kWh} \tag{148}$$

$$\Delta U_{in,01} = C_{in,01} \cdot (t_{a,in,01} - t_{a,in,01,1}) \tag{149}$$

$$C_{in,01} = ICF \cdot V_{in,01} \cdot c_{p,ref}/v_{ref} \tag{150}$$

$$\Delta U_{in,02} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,02} \, \mathrm{d}\tau \tag{151}$$

$$\Delta U_{in,kWh,02} = \frac{\Delta U_{in,02}}{J/kWh} \tag{152}$$

$$\Delta U_{in,02} = C_{in,02} \cdot (t_{a,in,02} - t_{a,in,02,1}) \tag{153}$$

$$C_{in,02} = ICF \cdot V_{in,02} \cdot c_{p,ref}/v_{ref} \tag{154}$$

$$\Delta U_{in,03} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,03} \, \mathrm{d}\tau \tag{155}$$

$$\Delta U_{in,kWh,03} = \frac{\Delta U_{in,03}}{J/kWh} \tag{156}$$

$$\Delta U_{in,03} = C_{in,03} \cdot (t_{a,in,03} - t_{a,in,03,1}) \tag{157}$$

$$C_{in,03} = ICF \cdot V_{in,03} \cdot c_{p,ref}/v_{ref} \tag{158}$$

$$\Delta U_{in,04} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,04} \, \mathrm{d}\tau \tag{159}$$

$$\Delta U_{in,kWh,04} = \frac{\Delta U_{in,04}}{J/kWh} \tag{160}$$

$$\Delta U_{in,04} = C_{in,04} \cdot (t_{a,in,04} - t_{a,in,04,1}) \tag{161}$$

$$C_{in,04} = ICF \cdot V_{in,04} \cdot c_{p,ref}/v_{ref} \tag{162}$$

$$\Delta U_{in,05} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,05} \, \mathrm{d}\tau \tag{163}$$

$$\Delta U_{in,kWh,05} = \frac{\Delta U_{in,05}}{J/kWh} \tag{164}$$

$$\Delta U_{in,05} = C_{in,05} \cdot (t_{a,in,05} - t_{a,in,05,1}) \tag{165}$$

$$C_{in,05} = ICF \cdot V_{in,05} \cdot c_{p,ref}/v_{ref} \tag{166}$$

$$\Delta U_{in,06} = \int_{\tau_1}^{\tau_2} \mathrm{d}U/\mathrm{d}tau_{in,06} \, \mathrm{d}\tau \tag{167}$$

$$\Delta U_{in,kWh,06} = \frac{\Delta U_{in,06}}{J/kWh} \tag{168}$$

$$\Delta U_{in,06} = C_{in,06} \cdot (t_{a,in,06} - t_{a,in,06,1}) \tag{169}$$

$$C_{in,06} = ICF \cdot V_{in,06} \cdot c_{p,ref}/v_{ref} \tag{170}$$

$$c_{p,ref} = c_{p,a} + \omega_{ref} \cdot c_{p,g} \tag{171}$$

(in fair approximation)

1.3.2 Heat gains from adjacent rooms through internal walls, ceiling and floor

$$\dot{Q}_{s,in,intwalls,01} = \dot{Q}_{02,01} + \dot{Q}_{04,01} + \dot{Q}_{05,01} + \dot{Q}_{06,01} + \dot{Q}_{floor,01} \tag{172}$$

$$\dot{Q}_{s,in,intwalls,02} = \dot{Q}_{01,02} + \dot{Q}_{03,02} + \dot{Q}_{05,02} + \dot{Q}_{06,02} + \dot{Q}_{floor,02} \tag{173}$$

$$\dot{Q}_{s,in,intwalls,03} = \dot{Q}_{02,03} + \dot{Q}_{04,03} + \dot{Q}_{05,03} + \dot{Q}_{06,03} + \dot{Q}_{floor,03} \tag{174}$$

$$\dot{Q}_{s,in,intwalls,04} = \dot{Q}_{03,04} + \dot{Q}_{01,04} + \dot{Q}_{05,04} + \dot{Q}_{06,04} + \dot{Q}_{floor,04} \tag{175}$$

$$\dot{Q}_{s,in,intwalls,05} = \dot{Q}_{01,05} + \dot{Q}_{02,05} + \dot{Q}_{03,05} + \dot{Q}_{04,05} + \dot{Q}_{06,05} + \dot{Q}_{floor,05} \tag{176}$$

$$\dot{Q}_{s,in,intwalls,06} = \dot{Q}_{01,06} + \dot{Q}_{02,06} + \dot{Q}_{03,06} + \dot{Q}_{04,06} + \dot{Q}_{05,06} + \dot{Q}_{floor,06} \tag{177}$$

1.3.2.1 Through internal walls and ceiling void (neglecting thermal mass's):

$$\dot{Q}_{02,01} = A_{1,2} \cdot U_{partition} \cdot (t_{a,in,02} - t_{a,in,01}) \tag{178}$$

$$\dot{Q}_{04,01} = A_{1,4} \cdot U_{partition} \cdot (t_{a,in,04} - t_{a,in,01}) \tag{179}$$

$$\dot{Q}_{05,01} = A_{1,5} \cdot U_{partition} \cdot (t_{a,in,05} - t_{a,in,01}) \tag{180}$$

$$\dot{Q}_{06,01} = A_{1} \cdot U_{partition} \cdot (t_{a,in,06} - t_{a,in,01}) \tag{181}$$

$$\dot{Q}_{01,02} = -\dot{Q}_{02,01} \tag{182}$$

$$\dot{Q}_{03,02} = A_{2,3} \cdot U_{partition} \cdot (t_{a,in,03} - t_{a,in,02}) \tag{183}$$

$$\dot{Q}_{05,02} = A_{2,5} \cdot U_{partition} \cdot (t_{a,in,05} - t_{a,in,02}) \tag{184}$$

$$\dot{Q}_{06,02} = A_{2} \cdot U_{partition} \cdot (t_{a,in,06} - t_{a,in,02}) \tag{185}$$

$$\dot{Q}_{02,03} = -\dot{Q}_{03,02} \tag{186}$$

$$\dot{Q}_{04,03} = A_{3,4} \cdot U_{partition} \cdot (t_{a,in,04} - t_{a,in,03}) \tag{187}$$

$$\dot{Q}_{05,03} = A_{3,5} \cdot U_{partition} \cdot (t_{a,in,05} - t_{a,in,03}) \tag{188}$$

$$\dot{Q}_{06,03} = A_{3} \cdot U_{partition} \cdot (t_{a,in,06} - t_{a,in,03}) \tag{189}$$

$$\dot{Q}_{03,04} = -\dot{Q}_{04,03} \tag{190}$$

$$\dot{Q}_{01,04} = -\dot{Q}_{04,01} \tag{191}$$

$$\dot{Q}_{05,04} = A_{4,5} \cdot U_{partition} \cdot (t_{a,in,05} - t_{a,in,04}) \tag{192}$$

$$\dot{Q}_{06,04} = A_4 \cdot U_{partition} \cdot (t_{a,in,06} - t_{a,in,04}) \tag{193}$$

$$\dot{Q}_{01,05} = -\dot{Q}_{05,01} \tag{194}$$

$$\dot{Q}_{02,05} = -\dot{Q}_{05,02} \tag{195}$$

$$\dot{Q}_{03,05} = -\dot{Q}_{05,03} \tag{196}$$

$$\dot{Q}_{04,05} = -\dot{Q}_{05,04} \tag{197}$$

$$\dot{Q}_{06,05} = A_5 \cdot U_{partition} \cdot (t_{a,in,06} - t_{a,in,05}) \tag{198}$$

$$\dot{Q}_{01,06} = -\dot{Q}_{06,01} \tag{199}$$

$$\dot{Q}_{02,06} = -\dot{Q}_{06,02} \tag{200}$$

$$\dot{Q}_{03,06} = -\dot{Q}_{06,03} \tag{201}$$

$$\dot{Q}_{04,06} = -\dot{Q}_{06,04} \tag{202}$$

$$\dot{Q}_{05,06} = -\dot{Q}_{06,05} \tag{203}$$

1.3.2.2 Through the floor:

Heat transfer from floor thermal mass:

$$\dot{Q}_{floor,01} = A_1 \cdot U_{floor} \cdot \frac{t_{floor,01} - t_{a,in,01}}{f_{\theta,floor}} \tag{204}$$

$$\dot{Q}_{floor,02} = A_2 \cdot U_{floor} \cdot \frac{t_{floor,02} - t_{a,in,02}}{f_{\theta,floor}} \tag{205}$$

$$\dot{Q}_{floor,03} = A_3 \cdot U_{floor} \cdot \frac{t_{floor,03} - t_{a,in,03}}{f_{\theta,floor}} \tag{206}$$

$$\dot{Q}_{floor,04} = A_4 \cdot U_{floor} \cdot \frac{t_{floor,04} - t_{a,in,04}}{f_{\theta,floor}} \tag{207}$$

$$\dot{Q}_{floor,05} = A_5 \cdot U_{floor} \cdot \frac{t_{floor,05} - t_{a,in,05}}{f_{\theta,floor}} \tag{208}$$

Heat transfer from indoor 08 to floor thermal mass:

$$\dot{Q}_{08,floor,01} = A_1 \cdot U_{floor} \cdot \frac{t_{a,in,08} - t_{floor,01}}{1 - f_{\theta,floor}} \tag{209}$$

$$\dot{Q}_{08,floor,02} = A_2 \cdot U_{floor} \cdot \frac{t_{a,in,08} - t_{floor,02}}{1 - f_{\theta,floor}} \tag{210}$$

$$\dot{Q}_{08,floor,03} = A_3 \cdot U_{floor} \cdot \frac{t_{a,in,08} - t_{floor,03}}{1 - f_{\theta,floor}} \tag{211}$$

$$\dot{Q}_{08,floor,04} = A_4 \cdot U_{floor} \cdot \frac{t_{a,in,08} - t_{floor,04}}{1 - f_{\theta,floor}} \tag{212}$$

$$\dot{Q}_{08,floor,05} = A_5 \cdot U_{floor} \cdot \frac{t_{a,in,08} - t_{floor,05}}{1 - f_{\theta,floor}} \tag{213}$$

Heat balance of floor:

$$\dot{Q}_{08,floor,01} - \dot{Q}_{floor,01} = \dot{Q}_{storage,floor,01} \tag{214}$$

$$\dot{Q}_{08,floor,02} - \dot{Q}_{floor,02} = \dot{Q}_{storage,floor,02} \tag{215}$$

$$\dot{Q}_{08,floor,03} - \dot{Q}_{floor,03} = \dot{Q}_{storage,floor,03} \tag{216}$$

$$\dot{Q}_{08,floor,04} - \dot{Q}_{floor,04} = \dot{Q}_{storage,floor,04} \tag{217}$$

$$\dot{Q}_{08,floor,05} - \dot{Q}_{floor,05} = \dot{Q}_{storage,floor,05} \tag{218}$$

Energy storage in floor thermal mass:

$$Q_{storage,floor,01} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,floor,01} \, \mathrm{d}\tau \tag{219}$$

$$Q_{storage,floor,01} = A_1 \cdot f_{\phi,floor} \cdot C/A_{floor} \cdot (t_{floor,01} - t_{floor,01,1}) \tag{220}$$

$$Q_{storage,floor,02} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,floor,02} \, \mathrm{d}\tau \tag{221}$$

$$Q_{storage,floor,02} = A_2 \cdot f_{\phi,floor} \cdot C/A_{floor} \cdot (t_{floor,02} - t_{floor,02,1}) \tag{222}$$

$$Q_{storage,floor,03} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,floor,03} \, \mathrm{d}\tau \tag{223}$$

$$Q_{storage,floor,03} = A_3 \cdot f_{\phi,floor} \cdot C/A_{floor} \cdot (t_{floor,03} - t_{floor,03,1}) \tag{224}$$

$$Q_{storage,floor,04} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,floor,04} \, \mathrm{d}\tau \tag{225}$$

$$Q_{storage,floor,04} = A_4 \cdot f_{\phi,floor} \cdot C/A_{floor} \cdot (t_{floor,04} - t_{floor,04,1}) \tag{226}$$

$$Q_{storage,floor,05} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,floor,05} \, \mathrm{d}\tau \tag{227}$$

$$Q_{storage,floor,05} = A_5 \cdot f_{\phi,floor} \cdot C/A_{floor} \cdot (t_{floor,05} - t_{floor,05,1}) \tag{228}$$

Initial temperatures (hypothetical):

$$t_{floor,01,1} = t_0 \tag{229}$$

$$t_{floor,02,1} = t_0 \tag{230}$$

$$t_{floor,03,1} = t_0 \tag{231}$$

$$t_{floor,04,1} = t_0 \tag{232}$$

$$t_{floor,05,1} = t_0 \tag{233}$$

Boundary condition:

$$t_{a,in,08} = t_{a,in,06} \tag{234}$$

1.3.2.3 Heat transfer from (upper) floor to ceiling void:

$$\dot{Q}_{floor,06} = -\dot{Q}_{08,floor,01} - \dot{Q}_{08,floor,02} - \dot{Q}_{08,floor,03} - \dot{Q}_{08,floor,04} - \dot{Q}_{08,floor,05} \tag{235}$$

———————————————————-

1.3.3 Enveloppe heat transmission:

Output:

$\dot{Q}_{envelope}$

Inputs:

t$_{out}$: see § 9

t$_{a,in,0j}$: outputs of §1.3.1

Parameters:

A$_{envelope}$

A$_{windows}$

U$_{windows}$

U$_{opaque,envelope}$

(NB: these heat transfer coefficients can be also affected by indoor air diffusion, which is itself affected by the ventilation and the emission of the terminal unit)

Simulation model:

$$\dot{Q}_{09,01} = \dot{Q}_{09,window,01} + \dot{Q}_{09,opaque,01} \quad (236)$$

$$\dot{Q}_{09,window,01} = A_{1,9,window} \cdot U_{window} \cdot (t_{out} - t_{a,in,01}) \quad (237)$$

$$\dot{Q}_{09,02} = \dot{Q}_{09,window,02} + \dot{Q}_{09,opaque,02} \quad (238)$$

$$\dot{Q}_{09,window,02} = A_{2,9,window} \cdot U_{window} \cdot (t_{out} - t_{a,in,02}) \quad (239)$$

$$\dot{Q}_{09,03} = \dot{Q}_{09,window,03} + \dot{Q}_{09,opaque,03} \quad (240)$$

$$\dot{Q}_{09,window,03} = A_{3,9,window} \cdot U_{window} \cdot (t_{out} - t_{a,in,03}) \quad (241)$$

$$\dot{Q}_{09,04} = \dot{Q}_{09,window,04} + \dot{Q}_{09,opaque,04} \quad (242)$$

$$\dot{Q}_{09,window,04} = A_{4,9,window} \cdot U_{window} \cdot (t_{out} - t_{a,in,04}) \quad (243)$$

$$\dot{Q}_{09,05} = 0 \ \text{[W]} \quad (244)$$

$$\dot{Q}_{09,06} = \dot{Q}_{09,opaque,06} \quad (245)$$

Heat transfer from opaque thermal mass to indoor:

$$\dot{Q}_{opaque,01} = A_{1,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{opaque,01} - t_{a,in,01}}{f_{\theta,wall}} \quad (246)$$

$$\dot{Q}_{opaque,02} = A_{2,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{opaque,02} - t_{a,in,02}}{f_{\theta,wall}} \quad (247)$$

$$\dot{Q}_{opaque,03} = A_{3,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{opaque,03} - t_{a,in,03}}{f_{\theta,wall}} \quad (248)$$

$$\dot{Q}_{opaque,04} = A_{4,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{opaque,04} - t_{a,in,04}}{f_{\theta,wall}} \quad (249)$$

$$\dot{Q}_{opaque,06} = A_{6,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{opaque,06} - t_{a,in,06}}{f_{\theta,wall}} \tag{250}$$

Heat transfer from outdoor environment to opaque thermal mass:

$$\dot{Q}_{09,opaque,01} = A_{1,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{out} - t_{opaque,01}}{1 - f_{\theta,wall}} \tag{251}$$

$$\dot{Q}_{09,opaque,02} = A_{2,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{out} - t_{opaque,02}}{1 - f_{\theta,wall}} \tag{252}$$

$$\dot{Q}_{09,opaque,03} = A_{3,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{out} - t_{opaque,03}}{1 - f_{\theta,wall}} \tag{253}$$

$$\dot{Q}_{09,opaque,04} = A_{4,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{out} - t_{opaque,04}}{1 - f_{\theta,wall}} \tag{254}$$

$$\dot{Q}_{09,opaque,06} = A_{6,9,opaque} \cdot U_{wall,out} \cdot \frac{t_{out} - t_{opaque,06}}{1 - f_{\theta,wall}} \tag{255}$$

Heat balance of opaque wall:

$$\dot{Q}_{09,opaque,01} - \dot{Q}_{opaque,01} = \dot{Q}_{storage,opaque,01} \tag{256}$$

$$\dot{Q}_{09,opaque,02} - \dot{Q}_{opaque,02} = \dot{Q}_{storage,opaque,02} \tag{257}$$

$$\dot{Q}_{09,opaque,03} - \dot{Q}_{opaque,03} = \dot{Q}_{storage,opaque,03} \tag{258}$$

$$\dot{Q}_{09,opaque,04} - \dot{Q}_{opaque,04} = \dot{Q}_{storage,opaque,04} \tag{259}$$

$$\dot{Q}_{09,opaque,06} - \dot{Q}_{opaque,06} = \dot{Q}_{storage,opaque,06} \tag{260}$$

Energy storage in opaque wall thermal mass:

$$Q_{storage,opaque,01} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,opaque,01} \, \mathrm{d}\tau \tag{261}$$

$$Q_{storage,opaque,01} = A_{1,9,opaque} \cdot f_{\phi,wall} \cdot C/A_{wall,out} \cdot (t_{opaque,01} - t_{opaque,01,1}) \tag{262}$$

$$Q_{storage,opaque,02} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,opaque,02} \, \mathrm{d}\tau \tag{263}$$

$$Q_{storage,opaque,02} = A_{2,9,opaque} \cdot f_{\phi,wall} \cdot C/A_{wall,out} \cdot (t_{opaque,02} - t_{opaque,02,1}) \tag{264}$$

$$Q_{storage,opaque,03} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,opaque,03} \, \mathrm{d}\tau \tag{265}$$

$$Q_{storage,opaque,03} = A_{3,9,opaque} \cdot f_{\phi,wall} \cdot C/A_{wall,out} \cdot (t_{opaque,03} - t_{opaque,03,1}) \tag{266}$$

$$Q_{storage,opaque,04} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,opaque,04} \, \mathrm{d}\tau \tag{267}$$

$$Q_{storage,opaque,04} = A_{4,9,opaque} \cdot f_{\phi,wall} \cdot C/A_{wall,out} \cdot (t_{opaque,04} - t_{opaque,04,1}) \tag{268}$$

$$Q_{storage,opaque,06} = \int_{\tau_1}^{\tau_2} \dot{Q}_{storage,opaque,06} \, \mathrm{d}\tau \tag{269}$$

$$Q_{storage,opaque,06} = A_{6,9,opaque} \cdot f_{\phi,wall} \cdot C/A_{wall,out} \cdot (t_{opaque,06} - t_{opaque,06,1}) \tag{270}$$

Initial temperatures (hypothetical):

$$t_{opaque,01,1} = t_0 \tag{271}$$

$$t_{opaque,02,1} = t_0 \tag{272}$$

$$t_{opaque,03,1} = t_0 \tag{273}$$

$$t_{opaque,04,1} = t_0 \tag{274}$$

$$t_{opaque,06,1} = t_0 \tag{275}$$

1.3.4 Ventilation sensible enthalpy flow rates supplied to the zones:

Outputs:

$\dot{H}_{s,vent,0j}$

Inputs:

$\dot{M}_{a,supplyduct,ex,0j}$: outputs of § 1.1.3

$t_{a,supplyduct,ex}$: output of § 4

$\dot{M}_{a,infiltr,0j}$: outputs of § 1.1

t_{out}: weather data (§11)

$t_{a,in,0j}$: outputs of §1.3.1

$\dot{M}_{a,zone,0j}$: outputs of § 1.1

Simulation model:

$$\dot{H}_{s,vent,01} = \dot{H}_{s,zone,su,01} - \dot{H}_{s,zone,ex,01} \tag{276}$$

$$\dot{H}_{s,zone,su,01} = \dot{M}_{a,zone,01} \cdot c_{p,ref} \cdot t_{a,zone,su,01} \tag{277}$$

(with $c_{p,ref}$ used here in fair approximation)

$$t_{a,zone,su,01} = t_{a,room,su,01} \tag{278}$$

(if the air is supplied directly inside the occupancy zone)

$$t_{a,room,su,01} = \frac{\dot{M}_{a,supplyduct,ex,01} \cdot t_{a,supplyduct,ex,01} + \dot{M}_{a,infiltr,01} \cdot t_{out}}{\dot{M}_{a,room,01}} \tag{279}$$

$$\dot{H}_{s,zone,ex,01} = \dot{M}_{a,zone,01} \cdot c_{p,ref} \cdot t_{a,in,01} \tag{280}$$

$$t_{a,supplyduct,ex,01} = t_{a,supplyduct,ex} \tag{281}$$

$$\dot{H}_{s,vent,02} = \dot{H}_{s,zone,su,02} - \dot{H}_{s,zone,ex,02} \tag{282}$$

$$\dot{H}_{s,zone,su,02} = \dot{M}_{a,zone,02} \cdot c_{p,ref} \cdot t_{a,zone,su,02} \tag{283}$$

$$t_{a,zone,su,02} = t_{a,room,su,02} \tag{284}$$

$$t_{a,room,su,02} = \frac{\dot{M}_{a,supplyduct,ex,02} \cdot t_{a,supplyduct,ex,02} + \dot{M}_{a,infiltr,02} \cdot t_{out}}{\dot{M}_{a,room,02}} \tag{285}$$

$$\dot{H}_{s,zone,ex,02} = \dot{M}_{a,zone,02} \cdot c_{p,ref} \cdot t_{a,in,02} \tag{286}$$

$$t_{a,supplyduct,ex,02} = t_{a,supplyduct,ex} \tag{287}$$

$$\dot{H}_{s,vent,03} = \dot{H}_{s,zone,su,03} - \dot{H}_{s,zone,ex,03} \tag{288}$$

$$\dot{H}_{s,zone,su,03} = \dot{M}_{a,zone,03} \cdot c_{p,ref} \cdot t_{a,zone,su,03} \tag{289}$$

$$t_{a,zone,su,03} = t_{a,room,su,03} \tag{290}$$

$$t_{a,room,su,03} = \frac{\dot{M}_{a,supplyduct,ex,03} \cdot t_{a,supplyduct,ex,03} + \dot{M}_{a,infiltr,03} \cdot t_{out}}{\dot{M}_{a,room,03}} \tag{291}$$

$$\dot{H}_{s,zone,ex,03} = \dot{M}_{a,zone,03} \cdot c_{p,ref} \cdot t_{a,in,03} \tag{292}$$

$$t_{a,supplyduct,ex,03} = t_{a,supplyduct,ex} \tag{293}$$

$$\dot{H}_{s,vent,04} = \dot{H}_{s,zone,su,04} - \dot{H}_{s,zone,ex,04} \tag{294}$$

$$\dot{H}_{s,zone,su,04} = \dot{M}_{a,zone,04} \cdot c_{p,ref} \cdot t_{a,zone,su,04} \tag{295}$$

$$t_{a,zone,su,04} = t_{a,room,su,04} \tag{296}$$

$$t_{a,room,su,04} = \frac{\dot{M}_{a,supplyduct,ex,04} \cdot t_{a,supplyduct,ex,04} + \dot{M}_{a,infiltr,04} \cdot t_{out}}{\dot{M}_{a,room,04}} \tag{297}$$

$$\dot{H}_{s,zone,ex,04} = \dot{M}_{a,zone,04} \cdot c_{p,ref} \cdot t_{a,in,04} \tag{298}$$

$$t_{a,supplyduct,ex,04} = t_{a,supplyduct,ex} \tag{299}$$

$$\dot{H}_{s,vent,05} = \dot{H}_{s,zone,su,05} - \dot{H}_{s,zone,ex,05} \tag{300}$$

$$\dot{H}_{s,zone,su,05} = \dot{M}_{a,zone,05} \cdot c_{p,ref} \cdot t_{a,zone,su,05} \tag{301}$$

$$t_{a,zone,su,05} = t_{a,room,su,05} \tag{302}$$

$$t_{a,room,su,05} = \frac{\dot{M}_{a,supplyduct,ex,05} \cdot t_{a,supplyduct,ex,05} + \dot{M}_{a,infiltr,05} \cdot t_{out}}{\dot{M}_{a,room,05}} \tag{303}$$

$$\dot{H}_{s,zone,ex,05} = \dot{M}_{a,zone,05} \cdot c_{p,ref} \cdot t_{a,in,05} \tag{304}$$

$$t_{a,supplyduct,ex,05} = t_{a,supplyduct,ex} \tag{305}$$

$$\dot{H}_{s,vent,floor} = \dot{H}_{s,vent,01} + \dot{H}_{s,vent,02} + \dot{H}_{s,vent,03} + \dot{H}_{s,vent,04} + \dot{H}_{s,vent,05} \tag{306}$$

$$\dot{H}_{s,vent} = n_{floor} \cdot \dot{H}_{s,vent,floor} \tag{307}$$

1.3.5 Room and zone sensible heat gains:

1.3.5.1 Occupancy:

Outputs:

$\dot{Q}_{s,occ,0j}$, A$_{floor}$ \n$_{occ,max,0j}$, $\tau_{occ,h,0j}$, $\bar{\tau}_{occ,h,0j}$

Input:

f$_{occ}$: see §10

Parameters:

Floor areas:

$$A_{floor,01} = A_1 \quad (308)$$

$$A_{floor,02} = A_2 \quad (309)$$

$$A_{floor,03} = A_3 \quad (310)$$

$$A_{floor,04} = A_4 \quad (311)$$

$$A_{floor,05} = A_5 \quad (312)$$

$$A_{floor,06} = A_6 \quad (313)$$

Maximal occupancy rates:

In each zone:

$$n_{occ,max,01} = 16 \ [\cdot] \quad (314)$$

$$n_{occ,max,02} = 10 \ [\cdot] \quad (315)$$

$$n_{occ,max,03} = 16 \ [\cdot] \quad (316)$$

$$n_{occ,max,04} = 10 \ [\cdot] \quad (317)$$

$$n_{occ,max,05} = 45 \ [\cdot] \quad (318)$$

$$n_{occ,max,06} = 0 \ [\cdot] \quad (319)$$

In the whole floor:

$$n_{occ,max,floor} = n_{occ,max,01} + n_{occ,max,02} + n_{occ,max,03} + n_{occ,max,04} + n_{occ,max,05} \quad (320)$$

And in the whole building:

$$n_{occ,max} = n_{floor} \cdot n_{occ,max,floor} \quad (321)$$

Average floor area available per occupant in maximal occupancy conditions:

$$A_{floor/n,occ,max,01} = A_{floor,01}/n_{occ,max,01} \quad (322)$$

$$A_{floor/n,occ,max,02} = A_{floor,02}/n_{occ,max,02} \quad (323)$$

$$A_{floor/n,occ,max,03} = A_{floor,03}/n_{occ,max,03} \quad (324)$$

$$A_{floor/n,occ,max,04} = A_{floor,04}/n_{occ,max,04} \quad (325)$$

$$A_{floor/n,occ,max,05} = A_{floor,05}/n_{occ,max,05} \quad (326)$$

Average sensible thermal power dissipated by each occupant:

$$\dot{Q}_{s,peroccupant} = 70 \ [\mathrm{W}] \quad (327)$$

Simulation:

Occupancy rates:

$$n_{occ,01} = f_{occ,01} \cdot n_{occ,max,01} \tag{328}$$

$$n_{occ,02} = f_{occ,02} \cdot n_{occ,max,02} \tag{329}$$

$$n_{occ,03} = f_{occ,03} \cdot n_{occ,max,03} \tag{330}$$

$$n_{occ,04} = f_{occ,04} \cdot n_{occ,max,04} \tag{331}$$

$$n_{occ,05} = f_{occ,05} \cdot n_{occ,max,05} \tag{332}$$

$$n_{occ,floor} = n_{occ,01} + n_{occ,02} + n_{occ,03} + n_{occ,04} + n_{occ,05} \tag{333}$$

$$n_{occ} = n_{floor} \cdot n_{occ,floor} \tag{334}$$

Corresponding occupancy times:

$\tau_{occ,01}$= integral(n$_{occ,01}$,τ,τ_1,τ_2, $\Delta\tau$)
$tau_{occ,01,h}$=$\tau_{occ,01}$/s \h
$t\bar{a}u_{occ,01,h}$=$\tau_{occ,01,h}$/n$_{occ,max,01}$

tau$_{occ,02}$= integral(n$_{occ,02}$,τ,τ_1,τ_2, $\Delta\tau$)
$tau_{occ,02,h}$=$\tau_{occ,02}$/s \h
$t\bar{a}u_{occ,02,h}$=$\tau_{occ,02,h}$/n$_{occ,max,02}$

tau$_{occ,03}$= integral(n$_{occ,03}$,τ,τ_1,τ_2, $\Delta\tau$)
$tau_{occ,03,h}$=$\tau_{occ,03}$/s \h
$t\bar{a}u_{occ,03,h}$=$\tau_{occ,03,h}$/n$_{occ,max,03}$

tau$_{occ,04}$= integral(n$_{occ,04}$,τ,τ_1,τ_2, $\Delta\tau$)
$tau_{occ,04,h}$=$\tau_{occ,04}$/s \h
$t\bar{a}u_{occ,04,h}$=$\tau_{occ,04,h}$/n$_{occ,max,04}$

tau$_{occ,05}$= integral(n$_{occ,05}$,τ,τ_1,τ_2, $\Delta\tau$)
$tau_{occ,05,h}$=$\tau_{occ,05}$/s \h
$t\bar{a}u_{occ,05,h}$=$\tau_{occ,05,h}$/n$_{occ,max,05}$

Sensible thermal power dissipated by the occupants:

$$\dot{Q}_{s,occ,01} = f_{occ,01} \cdot \dot{Q}_{s,occ,max,01} \tag{335}$$

$$\dot{Q}_{s,occ,max,01} = n_{occ,max,01} \cdot \dot{Q}_{s,peroccupant} \tag{336}$$

$$\dot{Q}_{s,occ,02} = f_{occ,02} \cdot \dot{Q}_{s,occ,max,02} \tag{337}$$

$$\dot{Q}_{s,occ,max,02} = n_{occ,max,02} \cdot \dot{Q}_{s,peroccupant} \tag{338}$$

$$\dot{Q}_{s,occ,03} = f_{occ,03} \cdot \dot{Q}_{s,occ,max,03} \tag{339}$$

$$\dot{Q}_{s,occ,max,03} = n_{occ,max,03} \cdot \dot{Q}_{s,peroccupant} \tag{340}$$

$$\dot{Q}_{s,occ,04} = f_{occ,04} \cdot \dot{Q}_{s,occ,max,04} \tag{341}$$

$$\dot{Q}_{s,occ,max,04} = n_{occ,max,04} \cdot \dot{Q}_{s,peroccupant} \tag{342}$$

$$\dot{Q}_{s,occ,05} = f_{occ,05} \cdot \dot{Q}_{s,occ,max,05} \tag{343}$$

$$\dot{Q}_{s,occ,max,05} = n_{occ,max,05} \cdot \dot{Q}_{s,peroccupant} \tag{344}$$

$$\dot{Q}_{s,occ,floor} = \dot{Q}_{s,occ,01} + \dot{Q}_{s,occ,02} + \dot{Q}_{s,occ,03} + \dot{Q}_{s,occ,04} + \dot{Q}_{s,occ,05} \tag{345}$$

$$\dot{Q}_{s,occ} = n_{floor} \cdot \dot{Q}_{s,occ,floor} \tag{346}$$

$$Q_{s,occ} = \int_{\tau_1}^{\tau_2} \dot{Q}_{s,occ} \, \mathrm{d}\tau \tag{347}$$

$$Q_{s,occ,kWh} = Q_{s,occ}/J/kWh \tag{348}$$

1.3.5.2 Lighting:

Outputs:

$\dot{W}_{light,0j}$

Inputs:

f$_{light,0j}$: see § 10

Parameters:

Installed lighting powers per unit of floor area

$\dot{W}_{light,max}$ \A$_{floor,01}$=10[W/m^2]
$\dot{W}_{light,max}$ \A$_{floor,02}$=10[W/m^2]
$\dot{W}_{light,max}$ \A$_{floor,03}$=10[W/m^2]
$\dot{W}_{light,max}$ \A$_{floor,04}$=10[W/m^2]
$\dot{W}_{light,max}$ \A$_{floor,05}$=10[W/m^2]

Corresponding powers (with the hypothesis that whole floor areas are lighted):

$\dot{W}_{light,max,01}$=A$_{floor,01}$*$\dot{W}_{light,max}$ \A$_{floor,01}$

$\dot{W}_{light,max,02}$=A$_{floor,02}$*$\dot{W}_{light,max}$ \A$_{floor,02}$

$\dot{W}_{light,max,03}$=A$_{floor,03}$*$\dot{W}_{light,max}$ \A$_{floor,03}$

$\dot{W}_{light,max,04}$=A$_{floor,04}$*$\dot{W}_{light,max}$ \A$_{floor,04}$

$\dot{W}_{light,max,05}$=A$_{floor,05}$*$\dot{W}_{light,max}$ \A$_{floor,05}$

$$\dot{W}_{light,max,01} = 2691 \ \mathrm{[W]} \tag{349}$$

$$\dot{W}_{light,max,02} = 1703 \ \mathrm{[W]} \tag{350}$$

$$\dot{W}_{light,max,03} = 2691 \ \mathrm{[W]} \tag{351}$$

$$\dot{W}_{light,max,04} = 1703 \ \mathrm{[W]} \tag{352}$$

$$\dot{W}_{light,max,05} = 12792 \ \mathrm{[W]} \tag{353}$$

$$\dot{W}_{light,max,06} = 0 \ \mathrm{[W]} \tag{354}$$

Simulation model: power and energy consumptions

For each zone:

$$\dot{W}_{light,01} = f_{light,01} \cdot \dot{W}_{light,max,01} \tag{355}$$

$$W_{light,01} = \int_{\tau_1}^{\tau_2} \dot{W}_{light,01}\ \mathrm{d}\tau \tag{356}$$

$$W_{light,kWh,01} = W_{light,01}/J/kWh \tag{357}$$

$$\dot{W}_{light,02} = f_{light,02} \cdot \dot{W}_{light,max,02} \tag{358}$$

$$W_{light,02} = \int_{\tau_1}^{\tau_2} \dot{W}_{light,02}\ \mathrm{d}\tau \tag{359}$$

$$W_{light,kWh,02} = W_{light,02}/J/kWh \tag{360}$$

$$\dot{W}_{light,03} = f_{light,03} \cdot \dot{W}_{light,max,03} \tag{361}$$

$$W_{light,03} = \int_{\tau_1}^{\tau_2} \dot{W}_{light,03}\ \mathrm{d}\tau \tag{362}$$

$$W_{light,kWh,03} = W_{light,03}/J/kWh \tag{363}$$

$$\dot{W}_{light,04} = f_{light,04} \cdot \dot{W}_{light,max,04} \tag{364}$$

$$W_{light,04} = \int_{\tau_1}^{\tau_2} \dot{W}_{light,04}\ \mathrm{d}\tau \tag{365}$$

$$W_{light,kWh,04} = W_{light,04}/J/kWh \tag{366}$$

$$\dot{W}_{light,05} = f_{light,05} \cdot \dot{W}_{light,max,05} \tag{367}$$

$$W_{light,05} = \int_{\tau_1}^{\tau_2} \dot{W}_{light,05}\ \mathrm{d}\tau \tag{368}$$

$$W_{light,kWh,05} = W_{light,05}/J/kWh \tag{369}$$

For the whole floor and for the whole building:

$$\dot{W}_{light,floor} = \dot{W}_{light,01} + \dot{W}_{light,02} + \dot{W}_{light,03} + \dot{W}_{light,04} + \dot{W}_{light,05} \tag{370}$$

$$\dot{W}_{light} = n_{floor} \cdot \dot{W}_{light,floor} \tag{371}$$

$$W_{light,kWh,floor} = W_{light,kWh,01} + W_{light,kWh,02} + W_{light,kWh,03} + W_{light,kWh,04} + W_{light,kWh,05} \tag{372}$$

$$W_{light,kWh} = n_{floor} \cdot W_{light,kWh,floor} \tag{373}$$

1.3.5.3 Appliances:

Outputs:

$\dot{W}_{appl,0j}$

Inputs:

f$_{appl,0j}$: see § 10

Parameters: installed equipment power per unit of floor area

$\dot{W}_{appl,max}$ \A$_{floor,01}$=5[W/m^2]
$\dot{W}_{appl,max}$ \A$_{floor,02}$=5[W/m^2]
$\dot{W}_{appl,max}$ \A$_{floor,03}$=5[W/m^2]

$\dot{W}_{appl,max}$ \A$_{floor,04}$=5[W/m^2]
$\dot{W}_{appl,max}$ \A$_{floor,05}$=5[W/m^2]

$\dot{W}_{appl,max,01}$=A$_{floor,01}$*$\dot{W}_{appl,max}$ \A$_{floor,01}$

$\dot{W}_{appl,max,02}$=A$_{floor,02}$*$\dot{W}_{appl,max}$ \A$_{floor,02}$

$\dot{W}_{appl,max,03}$=A$_{floor,03}$*$\dot{W}_{appl,max}$ \A$_{floor,03}$

$\dot{W}_{appl,max,04}$=A$_{floor,04}$*$\dot{W}_{appl,max}$ \A$_{floor,04}$

$\dot{W}_{appl,max,05}$=A$_{floor,05}$*$\dot{W}_{appl,max}$ \A$_{floor,05}$

$$\dot{W}_{appl,max,01} = 2073 \ [\text{W}] \tag{374}$$

$$\dot{W}_{appl,max,02} = 1313 \ [\text{W}] \tag{375}$$

$$\dot{W}_{appl,max,03} = 2073 \ [\text{W}] \tag{376}$$

$$\dot{W}_{appl,max,04} = 1313 \ [\text{W}] \tag{377}$$

$$\dot{W}_{appl,max,05} = 5904 \ [\text{W}] \tag{378}$$

$$\dot{W}_{appl,max,06} = 0 \ [\text{W}] \tag{379}$$

Simulation model:

$$\dot{W}_{appl,01} = f_{appl,01} \cdot \dot{W}_{appl,max,01} \tag{380}$$

$$W_{appl,01} = \int_{\tau_1}^{\tau_2} \dot{W}_{appl,01} \ \text{d}\tau \tag{381}$$

$$W_{appl,kWh,01} = W_{appl,01}/J/kWh \tag{382}$$

$$\dot{W}_{appl,02} = f_{appl,02} \cdot \dot{W}_{appl,max,02} \tag{383}$$

$$W_{appl,02} = \int_{\tau_1}^{\tau_2} \dot{W}_{appl,02} \ \text{d}\tau \tag{384}$$

$$W_{appl,kWh,02} = W_{appl,02}/J/kWh \tag{385}$$

$$\dot{W}_{appl,03} = f_{appl,03} \cdot \dot{W}_{appl,max,03} \tag{386}$$

$$W_{appl,03} = \int_{\tau_1}^{\tau_2} \dot{W}_{appl,03} \ \text{d}\tau \tag{387}$$

$$W_{appl,kWh,03} = W_{appl,03}/J/kWh \tag{388}$$

$$\dot{W}_{appl,04} = f_{appl,04} \cdot \dot{W}_{appl,max,04} \tag{389}$$

$$W_{appl,04} = \int_{\tau_1}^{\tau_2} \dot{W}_{appl,04} \ \text{d}\tau \tag{390}$$

$$W_{appl,kWh,04} = W_{appl,04}/J/kWh \tag{391}$$

$$\dot{W}_{appl,05} = f_{appl,05} \cdot \dot{W}_{appl,max,05} \tag{392}$$

$$W_{appl,05} = \int_{\tau_1}^{\tau_2} \dot{W}_{appl,05} \ \text{d}\tau \tag{393}$$

$$W_{appl,kWh,05} = W_{appl,05}/J/kWh \quad (394)$$

$$\dot{W}_{appl,floor} = \dot{W}_{appl,01} + \dot{W}_{appl,02} + \dot{W}_{appl,03} + \dot{W}_{appl,04} + \dot{W}_{appl,05} \quad (395)$$

$$\dot{W}_{appl} = n_{floor} \cdot \dot{W}_{appl,floor} \quad (396)$$

$$W_{appl,kWh,floor} = W_{appl,kWh,01} + W_{appl,kWh,02} + W_{appl,kWh,03} + W_{appl,kWh,04} + W_{appl,kWh,05} \quad (397)$$

$$W_{appl,kWh} = n_{floor} \cdot W_{appl,kWh,floor} \quad (398)$$

1.3.5.4 Sunshine:

Output:

$\dot{Q}_{sun}$

Inputs:

$\mathbf{I}_{glob}$, $\mathbf{I}_{diff}$, $\mathbf{F}_{south}$, $\mathbf{F}_{west}$, $\mathbf{F}_{east}$ and $\mathbf{F}_{north}$: see § 9

Parameters:

$$albedo = 0.2 \ [-] \quad (399)$$

windows total areas:

solar factor:

$\mathbf{SF}_{windows}$

(NB: for a better accuracy, the solar factor could be varied from one to another window and along the year)

$$SF_{windows} = S_{window} \quad (400)$$

$$\dot{Q}_{sun,01} = A_{1,9,window} \cdot SF_{windows} \cdot I_{sun,01} \quad (401)$$

$$Q_{sun,01} = \int_{\tau_1}^{\tau_2} \dot{Q}_{sun,01} \, \mathrm{d}\tau \quad (402)$$

$$Q_{sun,kWh,01} = Q_{sun,01}/J/kWh \quad (403)$$

$$I_{sun,01} = (I_{direct,01} + 0.5 \cdot I_{glob} \cdot albedo + 0.5 \cdot I_{diff}) \quad (404)$$

$$I_{direct,01} = (I_{glob} - I_{diff}) \cdot F_{01} \quad (405)$$

$$F_{01} = F_{North} \quad (406)$$

$$\dot{Q}_{sun,02} = A_{2,9,window} \cdot SF_{windows} \cdot I_{sun,02} \quad (407)$$

$$Q_{sun,02} = \int_{\tau_1}^{\tau_2} \dot{Q}_{sun,02} \, \mathrm{d}\tau \quad (408)$$

$$Q_{sun,kWh,02} = Q_{sun,02}/J/kWh \quad (409)$$

$$I_{sun,02} = (I_{direct,02} + 0.5 \cdot I_{glob} \cdot albedo + 0.5 \cdot I_{diff}) \quad (410)$$

$$I_{direct,02} = (I_{glob} - I_{diff}) \cdot F_{02} \quad (411)$$

$$F_{02} = F_{east} \quad (412)$$

$$\dot{Q}_{sun,03} = A_{3,9,window} \cdot SF_{windows} \cdot I_{sun,03} \quad (413)$$

$$Q_{sun,03} = \int_{\tau_1}^{\tau_2} \dot{Q}_{sun,03}\ \mathrm{d}\tau \tag{414}$$

$$Q_{sun,kWh,03} = Q_{sun,03}/J/kWh \tag{415}$$

$$I_{sun,03} = (I_{direct,03} + 0.5 \cdot I_{glob} \cdot albedo + 0.5 \cdot I_{diff}) \tag{416}$$

$$I_{direct,03} = (I_{glob} - I_{diff}) \cdot F_{03} \tag{417}$$

$$F_{03} = F_{South} \tag{418}$$

$$\dot{Q}_{sun,04} = A_{4,9,window} \cdot SF_{windows} \cdot I_{sun,04} \tag{419}$$

$$Q_{sun,04} = \int_{\tau_1}^{\tau_2} \dot{Q}_{sun,04}\ \mathrm{d}\tau \tag{420}$$

$$Q_{sun,kWh,04} = Q_{sun,04}/J/kWh \tag{421}$$

$$I_{sun,04} = (I_{direct,04} + 0.5 \cdot I_{glob} \cdot albedo + 0.5 \cdot I_{diff}) \tag{422}$$

$$I_{direct,04} = (I_{glob} - I_{diff}) \cdot F_{04} \tag{423}$$

$$F_{04} = F_{west} \tag{424}$$

$$\dot{Q}_{sun,05} = 0\ \text{[W]} \tag{425}$$

$$\dot{Q}_{sun,06} = 0\ \text{[W]} \tag{426}$$

$$\dot{Q}_{sun,floor} = \dot{Q}_{sun,01} + \dot{Q}_{sun,02} + \dot{Q}_{sun,03} + \dot{Q}_{sun,04} \tag{427}$$

$$\dot{Q}_{sun} = n_{floor} \cdot \dot{Q}_{sun,floor} \tag{428}$$

$$Q_{sun,kWh,floor} = Q_{sun,kWh,01} + Q_{sun,kWh,02} + Q_{sun,kWh,03} + Q_{sun,kWh,04} \tag{429}$$

$$Q_{sun,kWh} = n_{floor} \cdot Q_{sun,kWh,floor} \tag{430}$$

1.3.5.5 Sensible heating:

$\dot{Q}_{s,TUheating}$**: see** $\S$**5.1**

1.3.5.6 Sensible cooling:

$\dot{Q}_{s,TUcooling}$**: See** $\S$**5.2**

1.3.5.7 Room sensible heat gains:

$$\dot{Q}_{s,room,01} = \dot{Q}_{s,occ,01} + \dot{W}_{light,01} + \dot{W}_{appl,01} + \dot{Q}_{sun,01} + \dot{Q}_{s,heatingTU,01} - \dot{Q}_{s,coolingTU,01} \tag{431}$$

$$\dot{Q}_{s,room,02} = \dot{Q}_{s,occ,02} + \dot{W}_{light,02} + \dot{W}_{appl,02} + \dot{Q}_{sun,02} + \dot{Q}_{s,heatingTU,02} - \dot{Q}_{s,coolingTU,02} \tag{432}$$

$$\dot{Q}_{s,room,03} = \dot{Q}_{s,occ,03} + \dot{W}_{light,03} + \dot{W}_{appl,03} + \dot{Q}_{sun,03} + \dot{Q}_{s,heatingTU,03} - \dot{Q}_{s,coolingTU,03} \tag{433}$$

$$\dot{Q}_{s,room,04} = \dot{Q}_{s,occ,04} + \dot{W}_{light,04} + \dot{W}_{appl,04} + \dot{Q}_{sun,04} + \dot{Q}_{s,heatingTU,04} - \dot{Q}_{s,coolingTU,04} \tag{434}$$

$$\dot{Q}_{s,room,05} = \dot{Q}_{s,occ,05} + \dot{W}_{light,05} + \dot{W}_{appl,05} + \dot{Q}_{sun,05} + \dot{Q}_{s,heatingTU,05} - \dot{Q}_{s,coolingTU,05} \tag{435}$$

$$\dot{Q}_{s,room,06} = 0 \tag{436}$$

1.3.5.8 Zone sensible heat gains:

Parameters (NB: the following effectiveness's could be defined zone by zone):

Displacement effectiveness's of indoor air circulation for the different sources:

$$\epsilon_{occdispl} = 0 \; [-] \tag{437}$$

$$\epsilon_{lightdispl} = 0 \; [-] \tag{438}$$

(could be increased thanks to air extraction through lighting devices)

$$\epsilon_{appldispl} = 0 \; [-] \tag{439}$$

(could be increased thanks to efficient air diffusion)

$$\epsilon_{sundispl} = 0 \; [-] \tag{440}$$

(could also be also increased thanks to efficient air diffusion)

$$\epsilon_{heating} = 1 \; [-] \tag{441}$$

$$\epsilon_{cooling} = 1 \; [-] \tag{442}$$

(these last two effectiveness's might be lower than one because a part of the emission of the terminal unit is lost, i.e. not contributing in heating-up or cooling-down the occupancy zone; this could also have been taken into consideration by tuning the wall transmission coefficients or by defining different indoor temperatures)

Calculation:

$$\dot{Q}_{s,zone,01} = (1 - \epsilon_{occdispl}) \cdot \dot{Q}_{s,occ,01} + (1 - \epsilon_{lightdispl}) \cdot \dot{W}_{light,01} + (1 - \epsilon_{appldispl}) \cdot \dot{W}_{appl,01} + (1 - \epsilon_{sundispl}) \cdot \dot{Q}_{sun,01} + \epsilon_{heating} \cdot \dot{Q}_{s,heatin}$$

$$\dot{Q}_{s,zone,02} = (1 - \epsilon_{occdispl}) \cdot \dot{Q}_{s,occ,02} + (1 - \epsilon_{lightdispl}) \cdot \dot{W}_{light,02} + (1 - \epsilon_{appldispl}) \cdot \dot{W}_{appl,02} + (1 - \epsilon_{sundispl}) \cdot \dot{Q}_{sun,02} + \epsilon_{heating} \cdot \dot{Q}_{s,heatin}$$

$$\dot{Q}_{s,zone,03} = (1 - \epsilon_{occdispl}) \cdot \dot{Q}_{s,occ,03} + (1 - \epsilon_{lightdispl}) \cdot \dot{W}_{light,03} + (1 - \epsilon_{appldispl}) \cdot \dot{W}_{appl,03} + (1 - \epsilon_{sundispl}) \cdot \dot{Q}_{sun,03} + \epsilon_{heating} \cdot \dot{Q}_{s,heatin}$$

$$\dot{Q}_{s,zone,04} = (1 - \epsilon_{occdispl}) \cdot \dot{Q}_{s,occ,04} + (1 - \epsilon_{lightdispl}) \cdot \dot{W}_{light,04} + (1 - \epsilon_{appldispl}) \cdot \dot{W}_{appl,04} + (1 - \epsilon_{sundispl}) \cdot \dot{Q}_{sun,04} + \epsilon_{heating} \cdot \dot{Q}_{s,heatin}$$

$$\dot{Q}_{s,zone,05} = (1 - \epsilon_{occdispl}) \cdot \dot{Q}_{s,occ,05} + (1 - \epsilon_{lightdispl}) \cdot \dot{W}_{light,05} + (1 - \epsilon_{appldispl}) \cdot \dot{W}_{appl,05} + (1 - \epsilon_{sundispl}) \cdot \dot{Q}_{sun,05} + \epsilon_{heating} \cdot \dot{Q}_{s,heatin}$$

$$\dot{Q}_{s,zone,06} = 0 \tag{448}$$

1.3.6 Zone heat balance:

$$\mathrm{d}U/\mathrm{d}tau_{in,01} = \dot{Q}_{s,in,intwalls,01} + \dot{Q}_{09,01} + \dot{H}_{s,vent,01} + \dot{Q}_{s,zone,01} \tag{449}$$

$$\mathrm{d}U/\mathrm{d}tau_{in,02} = \dot{Q}_{s,in,intwalls,02} + \dot{Q}_{09,02} + \dot{H}_{s,vent,02} + \dot{Q}_{s,zone,02} \tag{450}$$

$$\mathrm{d}U/\mathrm{d}tau_{in,03} = \dot{Q}_{s,in,intwalls,03} + \dot{Q}_{09,03} + \dot{H}_{s,vent,03} + \dot{Q}_{s,zone,03} \tag{451}$$

$$\mathrm{d}U/\mathrm{d}tau_{in,04} = \dot{Q}_{s,in,intwalls,04} + \dot{Q}_{09,04} + \dot{H}_{s,vent,04} + \dot{Q}_{s,zone,04} \tag{452}$$

$$\mathrm{d}U/\mathrm{d}tau_{in,05} = \dot{Q}_{s,in,intwalls,05} + \dot{Q}_{09,05} + \dot{H}_{s,vent,05} + \dot{Q}_{s,zone,05} \tag{453}$$

$$\mathrm{d}U/\mathrm{d}tau_{in,06} = \dot{Q}_{s,in,intwalls,06} + \dot{Q}_{09,06} \tag{454}$$

1.3.7 Air temperature at room exhaust:

$$t_{a,room,ex,01} = \frac{\dot{M}_{a,zone,01} \cdot t_{a,in,01} + \left(\dot{M}_{a,room,01} - \dot{M}_{a,zone,01}\right) \cdot t_{a,room,su,01}}{\dot{M}_{a,room,01}} + \frac{\dot{Q}_{s,room,01} - \dot{Q}_{s,zone,01}}{\dot{M}_{a,room,01} \cdot c_{p,ref}} \tag{455}$$

$$t_{a,room,ex,02} = \frac{\dot{M}_{a,zone,02} \cdot t_{a,in,02} + \left(\dot{M}_{a,room,02} - \dot{M}_{a,zone,02}\right) \cdot t_{a,room,su,02}}{\dot{M}_{a,room,02}} + \frac{\dot{Q}_{s,room,02} - \dot{Q}_{s,zone,02}}{\dot{M}_{a,room,02} \cdot c_{p,ref}} \quad (456)$$

$$t_{a,room,ex,03} = \frac{\dot{M}_{a,zone,03} \cdot t_{a,in,03} + \left(\dot{M}_{a,room,03} - \dot{M}_{a,zone,03}\right) \cdot t_{a,room,su,03}}{\dot{M}_{a,room,03}} + \frac{\dot{Q}_{s,room,03} - \dot{Q}_{s,zone,03}}{\dot{M}_{a,room,03} \cdot c_{p,ref}} \quad (457)$$

$$t_{a,room,ex,04} = \frac{\dot{M}_{a,zone,04} \cdot t_{a,in,04} + \left(\dot{M}_{a,room,04} - \dot{M}_{a,zone,04}\right) \cdot t_{a,room,su,04}}{\dot{M}_{a,room,04}} + \frac{\dot{Q}_{s,room,04} - \dot{Q}_{s,zone,04}}{\dot{M}_{a,room,04} \cdot c_{p,ref}} \quad (458)$$

$$t_{a,room,ex,05} = \frac{\dot{M}_{a,zone,05} \cdot t_{a,in,05} + \left(\dot{M}_{a,room,05} - \dot{M}_{a,zone,05}\right) \cdot t_{a,room,su,05}}{\dot{M}_{a,room,05}} + \frac{\dot{Q}_{s,room,05} - \dot{Q}_{s,zone,05}}{\dot{M}_{a,room,05} \cdot c_{p,ref}} \quad (459)$$

(with $t_{a,room,su,0j}$ given in § 1.3.4)

1.4 Zone water balance:

1.4.1 Zone internal water storage model:

Outputs:

$\omega_{in,0j}$, $RH_{in,0j}$,

Inputs:

$$\omega_{in,01,1} = 0.005 \quad (460)$$

$$\omega_{in,02,1} = 0.005 \quad (461)$$

$$\omega_{in,03,1} = 0.005 \quad (462)$$

$$\omega_{in,04,1} = 0.005 \quad (463)$$

$$\omega_{in,05,1} = 0.005 \quad (464)$$

dMwin \dtau$_{0j}$: outputs of §1.4.6

$t_{a,in,0j}$: outputs of § 1.3.1

p_{atm}: see § 9

Parameters:

Volumes:

$V_{in,0j}$: see § 1.3.1

Indoor capacity factor and time:

(see § 1.3.1)

Simulation model:

$$\Delta M_{w,in,01} = \int_{\tau_1}^{\tau_2} \mathrm{d}Mwin/\mathrm{d}tau_{01} \, \mathrm{d}\tau \quad (465)$$

$$\Delta M_{w,in,01} = C_{w,in,01} \cdot (\omega_{in,01} - \omega_{in,01,1}) \quad (466)$$

$$C_{w,in,01} = ICF \cdot V_{in,01}/v_a \tag{467}$$

$$p_{w,in,01} = p_{atm} \cdot \frac{\omega_{in,01}}{0.622 + \omega_{in,01}} \tag{468}$$

$$p_{w,s,in,01}/pascal = \exp\left(\left(A \cdot \frac{t_{a,in,01}/Celsius}{B + t_{a,in,01}/Celsius}\right) + C\right) \tag{469}$$

$$RH_{in,01} = p_{w,in,01}/p_{w,s,in,01} \tag{470}$$

$$\Delta M_{w,in,02} = \int_{\tau_1}^{\tau_2} \mathrm{d}Mwin/\mathrm{d}tau_{02}\, \mathrm{d}\tau \tag{471}$$

$$\Delta M_{w,in,02} = C_{w,in,02} \cdot (\omega_{in,02} - \omega_{in,02,1}) \tag{472}$$

$$C_{w,in,02} = ICF \cdot V_{in,02}/v_a \tag{473}$$

$$p_{w,in,02} = p_{atm} \cdot \frac{\omega_{in,02}}{0.622 + \omega_{in,02}} \tag{474}$$

$$p_{w,s,in,02}/pascal = \exp\left(\left(A \cdot \frac{t_{a,in,02}/Celsius}{B + t_{a,in,02}/Celsius}\right) + C\right) \tag{475}$$

$$RH_{in,02} = p_{w,in,02}/p_{w,s,in,02} \tag{476}$$

$$\Delta M_{w,in,03} = \int_{\tau_1}^{\tau_2} \mathrm{d}Mwin/\mathrm{d}tau_{03}\, \mathrm{d}\tau \tag{477}$$

$$\Delta M_{w,in,03} = C_{w,in,03} \cdot (\omega_{in,03} - \omega_{in,03,1}) \tag{478}$$

$$C_{w,in,03} = ICF \cdot V_{in,03}/v_a \tag{479}$$

$$p_{w,in,03} = p_{atm} \cdot \frac{\omega_{in,03}}{0.622 + \omega_{in,03}} \tag{480}$$

$$p_{w,s,in,03}/pascal = \exp\left(\left(A \cdot \frac{t_{a,in,03}/Celsius}{B + t_{a,in,03}/Celsius}\right) + C\right) \tag{481}$$

$$RH_{in,03} = p_{w,in,03}/p_{w,s,in,03} \tag{482}$$

$$\Delta M_{w,in,04} = \int_{\tau_1}^{\tau_2} \mathrm{d}Mwin/\mathrm{d}tau_{04}\, \mathrm{d}\tau \tag{483}$$

$$\Delta M_{w,in,04} = C_{w,in,04} \cdot (\omega_{in,04} - \omega_{in,04,1}) \tag{484}$$

$$C_{w,in,04} = ICF \cdot V_{in,04}/v_a \tag{485}$$

$$p_{w,in,04} = p_{atm} \cdot \frac{\omega_{in,04}}{0.622 + \omega_{in,04}} \tag{486}$$

$$p_{w,s,in,04}/pascal = \exp\left(\left(A \cdot \frac{t_{a,in,04}/Celsius}{B + t_{a,in,04}/Celsius}\right) + C\right) \tag{487}$$

$$RH_{in,04} = p_{w,in,04}/p_{w,s,in,04} \tag{488}$$

$$\Delta M_{w,in,05} = \int_{\tau_1}^{\tau_2} \mathrm{d}Mwin/\mathrm{d}tau_{05}\, \mathrm{d}\tau \tag{489}$$

$$\Delta M_{w,in,05} = C_{w,in,05} \cdot (\omega_{in,05} - \omega_{in,05,1}) \tag{490}$$

$$C_{w,in,05} = ICF \cdot V_{in,05}/v_a \tag{491}$$

$$p_{w,in,05} = p_{atm} \cdot \frac{\omega_{in,05}}{0.622 + \omega_{in,05}} \tag{492}$$

$$p_{w,s,in,05}/pascal = \exp\left(\left(A \cdot \frac{t_{a,in,05}/Celsius}{B + t_{a,in,05}/Celsius}\right) + C\right) \tag{493}$$

$$RH_{in,05} = p_{w,in,05}/p_{w,s,in,05} \tag{494}$$

1.4.2 Ventilation water flowrate:

Outputs:

$\dot{M}_{w,vent,0j}$

Inputs:

$\dot{M}_{a,supplyduct,ex,0j}$: outputs of § 4

$\omega_{supplyduct,ex,0j}$**: outputs of** § **4**

$\dot{M}_{a,infiltr,0j}$: outputs of § 1.1

t$_{out}$ **and RH**$_{out}$**: weather data (**§**9)**

$\omega_{in,0j}$: outputs of §1.3.1

$\dot{M}_{a,zone,0j}$: outputs of § 1.1

Simulation model:

$$\omega_{out} = 0.622 \cdot \frac{p_{w,out}}{p_{atm} - p_{w,out}} \tag{495}$$

$$p_{w,out} = RH_{out} \cdot p_{w,s,out} \tag{496}$$

$$p_{w,s,out}/pascal = \exp\left(\left(A \cdot \frac{t_{out}/celsius}{B + t_{out}/celsius}\right) + C\right) \tag{497}$$

$$\dot{M}_{w,vent,01} = \dot{M}_{w,zone,su,01} - \dot{M}_{w,zone,ex,01} \tag{498}$$

$$\dot{M}_{w,zone,su,01} = \dot{M}_{a,zone,01} \cdot \omega_{zone,su,01} \tag{499}$$

$$\omega_{zone,su,01} = \omega_{room,su,01} \tag{500}$$

$$\omega_{room,su,01} = \frac{\dot{M}_{a,supplyduct,ex,01} \cdot \omega_{supplyduct,ex,01} + \dot{M}_{a,infiltr,01} \cdot \omega_{out}}{\dot{M}_{a,room,01}} \tag{501}$$

$$\dot{M}_{w,zone,ex,01} = \dot{M}_{a,zone,01} \cdot \omega_{in,01} \tag{502}$$

$$\omega_{supplyduct,ex,01} = \omega_{supplyduct,ex} \tag{503}$$

$$\dot{M}_{w,vent,02} = \dot{M}_{w,zone,su,02} - \dot{M}_{w,zone,ex,02} \tag{504}$$

$$\dot{M}_{w,zone,su,02} = \dot{M}_{a,zone,02} \cdot \omega_{zone,su,02} \tag{505}$$

$$\omega_{zone,su,02} = \omega_{room,su,02} \tag{506}$$

$$\omega_{room,su,02} = \frac{\dot{M}_{a,supplyduct,ex,02} \cdot \omega_{supplyduct,ex,02} + \dot{M}_{a,infiltr,02} \cdot \omega_{out}}{\dot{M}_{a,room,02}} \quad (507)$$

$$\dot{M}_{w,zone,ex,02} = \dot{M}_{a,zone,02} \cdot \omega_{in,02} \quad (508)$$

$$\omega_{supplyduct,ex,02} = \omega_{supplyduct,ex} \quad (509)$$

$$\dot{M}_{w,vent,03} = \dot{M}_{w,zone,su,03} - \dot{M}_{w,zone,ex,03} \quad (510)$$

$$\dot{M}_{w,zone,su,03} = \dot{M}_{a,zone,03} \cdot \omega_{zone,su,03} \quad (511)$$

$$\omega_{zone,su,03} = \omega_{room,su,03} \quad (512)$$

$$\omega_{room,su,03} = \frac{\dot{M}_{a,supplyduct,ex,03} \cdot \omega_{supplyduct,ex,03} + \dot{M}_{a,infiltr,03} \cdot \omega_{out}}{\dot{M}_{a,room,03}} \quad (513)$$

$$\dot{M}_{w,zone,ex,03} = \dot{M}_{a,zone,03} \cdot \omega_{in,03} \quad (514)$$

$$\omega_{supplyduct,ex,03} = \omega_{supplyduct,ex} \quad (515)$$

$$\dot{M}_{w,vent,04} = \dot{M}_{w,zone,su,04} - \dot{M}_{w,zone,ex,04} \quad (516)$$

$$\dot{M}_{w,zone,su,04} = \dot{M}_{a,zone,04} \cdot \omega_{zone,su,04} \quad (517)$$

$$\omega_{zone,su,04} = \omega_{room,su,04} \quad (518)$$

$$\omega_{room,su,04} = \frac{\dot{M}_{a,supplyduct,ex,04} \cdot \omega_{supplyduct,ex,04} + \dot{M}_{a,infiltr,04} \cdot \omega_{out}}{\dot{M}_{a,room,04}} \quad (519)$$

$$\dot{M}_{w,zone,ex,04} = \dot{M}_{a,zone,04} \cdot \omega_{in,04} \quad (520)$$

$$\omega_{supplyduct,ex,04} = \omega_{supplyduct,ex} \quad (521)$$

$$\dot{M}_{w,vent,05} = \dot{M}_{w,zone,su,05} - \dot{M}_{w,zone,ex,05} \quad (522)$$

$$\dot{M}_{w,zone,su,05} = \dot{M}_{a,zone,05} \cdot \omega_{zone,su,05} \quad (523)$$

$$\omega_{zone,su,05} = \omega_{room,su,05} \quad (524)$$

$$\omega_{room,su,05} = \frac{\dot{M}_{a,supplyduct,ex,05} \cdot \omega_{supplyduct,ex,05} + \dot{M}_{a,infiltr,05} \cdot \omega_{out}}{\dot{M}_{a,room,05}} \quad (525)$$

$$\dot{M}_{w,zone,ex,05} = \dot{M}_{a,zone,05} \cdot \omega_{in,05} \quad (526)$$

$$\omega_{supplyduct,ex,05} = \omega_{supplyduct,ex} \quad (527)$$

1.4.3 Internal water production:

Outputs:

$\dot{M}_{w,in,0j}$

Inputs:

$f_{occ,0j}$: see §10

water production per occupant:

$$\dot{M}_{w,peroccupant,gh} = 40 \ \text{[g/h]} \quad (528)$$

Parameters:

$n_{occ,max}$: see §1.3.5

Simulation model:

$$\dot{M}_{w,occ,01} = f_{occ,01} \cdot \dot{M}_{w,occ,max,01} \quad (529)$$

$$\dot{M}_{w,occ,max,01} = n_{occ,max,01} \cdot \frac{\dot{M}_{w,peroccupant,gh}}{s/h \cdot gkg} \quad (530)$$

$$\dot{M}_{w,occ,02} = f_{occ,02} \cdot \dot{M}_{w,occ,max,02} \quad (531)$$

$$\dot{M}_{w,occ,max,02} = n_{occ,max,02} \cdot \frac{\dot{M}_{w,peroccupant,gh}}{s/h \cdot gkg} \quad (532)$$

$$\dot{M}_{w,occ,03} = f_{occ,03} \cdot \dot{M}_{w,occ,max,03} \quad (533)$$

$$\dot{M}_{w,occ,max,03} = n_{occ,max,03} \cdot \frac{\dot{M}_{w,peroccupant,gh}}{s/h \cdot gkg} \quad (534)$$

$$\dot{M}_{w,occ,04} = f_{occ,04} \cdot \dot{M}_{w,occ,max,04} \quad (535)$$

$$\dot{M}_{w,occ,max,04} = n_{occ,max,04} \cdot \frac{\dot{M}_{w,peroccupant,gh}}{s/h \cdot gkg} \quad (536)$$

$$\dot{M}_{w,occ,05} = f_{occ,05} \cdot \dot{M}_{w,occ,max,05} \quad (537)$$

$$\dot{M}_{w,occ,max,05} = n_{occ,max,05} \cdot \frac{\dot{M}_{w,peroccupant,gh}}{s/h \cdot gkg} \quad (538)$$

———————————————————-

1.4.4 Room water gain, if no other water source (as boiling, cooking, etc.) or water sink (as condensation in terminal unit...) to be considered:

$$\dot{M}_{w,room,01} = \dot{M}_{w,occ,01} \quad (539)$$

$$\dot{M}_{w,room,02} = \dot{M}_{w,occ,02} \quad (540)$$

$$\dot{M}_{w,room,03} = \dot{M}_{w,occ,03} \quad (541)$$

$$\dot{M}_{w,room,04} = \dot{M}_{w,occ,04} \quad (542)$$

$$\dot{M}_{w,room,05} = \dot{M}_{w,occ,05} \quad (543)$$

———————————————————-

1.4.5 Zone water gain:

$$\dot{M}_{w,zone,01} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{w,occ,01} \quad (544)$$

$$M_{w,zone,01} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,zone,01} \, \mathrm{d}\tau \quad (545)$$

$$\dot{M}_{w,zone,02} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{w,occ,02} \tag{546}$$

$$M_{w,zone,02} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,zone,02}\ \mathrm{d}\tau \tag{547}$$

$$\dot{M}_{w,zone,03} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{w,occ,03} \tag{548}$$

$$M_{w,zone,03} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,zone,03}\ \mathrm{d}\tau \tag{549}$$

$$\dot{M}_{w,zone,04} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{w,occ,04} \tag{550}$$

$$M_{w,zone,04} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,zone,04}\ \mathrm{d}\tau \tag{551}$$

$$\dot{M}_{w,zone,05} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{w,occ,05} \tag{552}$$

$$M_{w,zone,05} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,zone,05}\ \mathrm{d}\tau \tag{553}$$

———————————————-

1.4.6 Zone water balance:

$$\mathrm{d}Mwin/\mathrm{d}tau_{01} = \dot{M}_{w,vent,01} + \dot{M}_{w,zone,01} \tag{554}$$

$$\mathrm{d}Mwin/\mathrm{d}tau_{02} = \dot{M}_{w,vent,02} + \dot{M}_{w,zone,02} \tag{555}$$

$$\mathrm{d}Mwin/\mathrm{d}tau_{03} = \dot{M}_{w,vent,03} + \dot{M}_{w,zone,03} \tag{556}$$

$$\mathrm{d}Mwin/\mathrm{d}tau_{04} = \dot{M}_{w,vent,04} + \dot{M}_{w,zone,04} \tag{557}$$

$$\mathrm{d}Mwin/\mathrm{d}tau_{05} = \dot{M}_{w,vent,05} + \dot{M}_{w,zone,05} \tag{558}$$

———————————————-

1.4.7 Air humidity ratio at room exhaust:

$$\omega_{room,ex,01} = \frac{\dot{M}_{a,zone,01} \cdot \omega_{in,01} + \left(\dot{M}_{a,room,01} - \dot{M}_{a,zone,01}\right) \cdot \omega_{room,su,01}}{\dot{M}_{a,room,01}} + \frac{\dot{M}_{w,room,01} - \dot{M}_{w,zone,01}}{\dot{M}_{a,room,01}} \tag{559}$$

$$\omega_{room,ex,02} = \frac{\dot{M}_{a,zone,02} \cdot \omega_{in,02} + \left(\dot{M}_{a,room,02} - \dot{M}_{a,zone,02}\right) \cdot \omega_{room,su,02}}{\dot{M}_{a,room,02}} + \frac{\dot{M}_{w,room,02} - \dot{M}_{w,zone,02}}{\dot{M}_{a,room,02}} \tag{560}$$

$$\omega_{room,ex,03} = \frac{\dot{M}_{a,zone,03} \cdot \omega_{in,03} + \left(\dot{M}_{a,room,03} - \dot{M}_{a,zone,03}\right) \cdot \omega_{room,su,03}}{\dot{M}_{a,room,03}} + \frac{\dot{M}_{w,room,03} - \dot{M}_{w,zone,03}}{\dot{M}_{a,room,03}} \tag{561}$$

$$\omega_{room,ex,04} = \frac{\dot{M}_{a,zone,04} \cdot \omega_{in,04} + \left(\dot{M}_{a,room,04} - \dot{M}_{a,zone,04}\right) \cdot \omega_{room,su,04}}{\dot{M}_{a,room,04}} + \frac{\dot{M}_{w,room,04} - \dot{M}_{w,zone,04}}{\dot{M}_{a,room,04}} \tag{562}$$

$$\omega_{room,ex,05} = \frac{\dot{M}_{a,zone,05} \cdot \omega_{in,05} + \left(\dot{M}_{a,room,05} - \dot{M}_{a,zone,05}\right) \cdot \omega_{room,su,05}}{\dot{M}_{a,room,05}} + \frac{\dot{M}_{w,room,05} - \dot{M}_{w,zone,05}}{\dot{M}_{a,room,05}} \tag{563}$$

———————————————-

1.5 Zone CO2 balance:

1.5.1 Zone internal CO2 storage model:

Outputs:

$X_{CO2,in,0j}$,

Inputs:

$$X_{CO2,in,01,1} = 0.0004 \text{ [kmol/kmol]} \quad (564)$$

$$X_{CO2,in,02,1} = 0.0004 \text{ [kmol/kmol]} \quad (565)$$

$$X_{CO2,in,03,1} = 0.0004 \text{ [kmol/kmol]} \quad (566)$$

$$X_{CO2,in,04,1} = 0.0004 \text{ [kmol/kmol]} \quad (567)$$

$$X_{CO2,in,05,1} = 0.0004 \text{ [kmol/kmol]} \quad (568)$$

dMCO2in \dtau$_{0j}$: outputs of §1.5.6

Parameters:

Volumes:

$V_{in,0j}$: see § 1.3.1

Indoor capacity factor and time: see § 1.3.1

Simulation model:

$$\Delta M_{CO2,in,01} = \int_{\tau_1}^{\tau_2} \mathrm{d}MCO2in/\mathrm{d}tau_{01}\, \mathrm{d}\tau \quad (569)$$

$$\Delta M_{CO2,in,01} = C_{CO2,in,01} \cdot (X_{CO2,in,01} - X_{CO2,in,01,1}) \quad (570)$$

$$C_{CO2,in,01} = MM_{CO2} \cdot \frac{V_{in,01}}{v_a \cdot MM_{dryair}} \quad (571)$$

(NB: no internal capacity factor effect, because no CO2 absorption by furnitures)

$$\Delta M_{CO2,in,02} = \int_{\tau_1}^{\tau_2} \mathrm{d}MCO2in/\mathrm{d}tau_{02}\, \mathbf{d}\tau \quad (572)$$

$$\Delta M_{CO2,in,02} = C_{CO2,in,02} \cdot (X_{CO2,in,02} - X_{CO2,in,02,1}) \quad (573)$$

$$C_{CO2,in,02} = MM_{CO2} \cdot \frac{V_{in,02}}{v_a \cdot MM_{dryair}} \quad (574)$$

$$\Delta M_{CO2,in,03} = \int_{\tau_1}^{\tau_2} \mathrm{d}MCO2in/\mathrm{d}tau_{03}\, \mathbf{d}\tau \quad (575)$$

$$\Delta M_{CO2,in,03} = C_{CO2,in,03} \cdot (X_{CO2,in,03} - X_{CO2,in,03,1}) \quad (576)$$

$$C_{CO2,in,03} = MM_{CO2} \cdot \frac{V_{in,03}}{v_a \cdot MM_{dryair}} \quad (577)$$

$$\Delta M_{CO2,in,04} = \int_{\tau_1}^{\tau_2} \mathrm{d}MCO2in/\mathrm{d}tau_{04}\, \mathbf{d}\tau \quad (578)$$

$$\Delta M_{CO2,in,04} = C_{CO2,in,04} \cdot (X_{CO2,in,04} - X_{CO2,in,04,1}) \quad (579)$$

$$C_{CO2,in,04} = MM_{CO2} \cdot \frac{V_{in,04}}{v_a \cdot MM_{dryair}} \quad (580)$$

$$\Delta M_{CO2,in,05} = \int_{\tau_1}^{\tau_2} \mathrm{d}MCO2in/\mathrm{d}tau_{05} \, \mathbf{d}\tau \quad (581)$$

$$\Delta M_{CO2,in,05} = C_{CO2,in,05} \cdot (X_{CO2,in,05} - X_{CO2,in,05,1}) \quad (582)$$

$$C_{CO2,in,05} = MM_{CO2} \cdot \frac{V_{in,05}}{v_a \cdot MM_{dryair}} \quad (583)$$

1.5.2 Ventilation CO2 flowrate:

Outputs:

$\dot{M}_{CO2,vent,0j}$

Inputs:

$\dot{M}_{a,supplyduct,ex,0j}$: outputs of § 4

$\mathbf{X}_{CO2,supplyduct,ex,0j}$: outputs of § 4

$\dot{M}_{a,infiltr,0j}$: outputs of § 1.1

$$X_{CO2,out} = 0.0004 \ \text{[kmol/kmol]} \quad (584)$$

$\mathrm{X}_{CO2,in,0j}$: outputs of §1.3.1

$\dot{M}_{a,zone,0j}$: outputs of § 1.1

Simulation model:

$$\dot{M}_{CO2,vent,01} = \dot{M}_{CO2,zone,su,01} - \dot{M}_{CO2,zone,ex,01} \quad (585)$$

$$\dot{M}_{CO2,zone,su,01} = \dot{MM}_{a,zone,01} \cdot X_{CO2,zone,su,01} \cdot MM_{CO2} \quad (586)$$

$$\dot{MM}_{a,zone,01} = \dot{M}_{a,zone,01}/MM_{dryair} \quad (587)$$

$$X_{CO2,zone,su,01} = X_{CO2,room,su,01} \quad (588)$$

$$X_{CO2,room,su,01} = \frac{\dot{M}_{a,supplyduct,ex,01} \cdot X_{CO2,supplyduct,ex,01} + \dot{M}_{a,infiltr,01} \cdot X_{CO2,out}}{\dot{M}_{a,room,01}} \quad (589)$$

$$\dot{M}_{CO2,zone,ex,01} = \dot{MM}_{a,zone,01} \cdot X_{CO2,in,01} \cdot MM_{CO2} \quad (590)$$

$$X_{CO2,supplyduct,ex,01} = X_{CO2,supplyduct,ex} \quad (591)$$

$$\dot{M}_{CO2,vent,02} = \dot{M}_{CO2,zone,su,02} - \dot{M}_{CO2,zone,ex,02} \quad (592)$$

$$\dot{M}_{CO2,zone,su,02} = \dot{MM}_{a,zone,02} \cdot X_{CO2,zone,su,02} \cdot MM_{CO2} \quad (593)$$

$$\dot{MM}_{a,zone,02} = \dot{M}_{a,zone,02}/MM_{dryair} \quad (594)$$

$$X_{CO2,zone,su,02} = X_{CO2,room,su,02} \quad (595)$$

$$X_{CO2,room,su,02} = \frac{\dot{M}_{a,supplyduct,ex,02} \cdot X_{CO2,supplyduct,ex,02} + \dot{M}_{a,infiltr,02} \cdot X_{CO2,out}}{\dot{M}_{a,room,02}} \quad (596)$$

$$\dot{M}_{CO2,zone,ex,02} = \dot{MM}_{a,zone,02} \cdot X_{CO2,in,02} \cdot MM_{CO2} \quad (597)$$

$$X_{CO2,supplyduct,ex,02} = X_{CO2,supplyduct,ex} \quad (598)$$

$$\dot{M}_{CO2,vent,03} = \dot{M}_{CO2,zone,su,03} - \dot{M}_{CO2,zone,ex,03} \quad (599)$$

$$\dot{M}_{CO2,zone,su,03} = \dot{MM}_{a,zone,03} \cdot X_{CO2,zone,su,03} \cdot MM_{CO2} \quad (600)$$

$$\dot{MM}_{a,zone,03} = \dot{M}_{a,zone,03}/MM_{dryair} \quad (601)$$

$$X_{CO2,zone,su,03} = X_{CO2,room,su,03} \quad (602)$$

$$X_{CO2,room,su,03} = \frac{\dot{M}_{a,supplyduct,ex,03} \cdot X_{CO2,supplyduct,ex,03} + \dot{M}_{a,infiltr,03} \cdot X_{CO2,out}}{\dot{M}_{a,room,03}} \quad (603)$$

$$\dot{M}_{CO2,zone,ex,03} = \dot{MM}_{a,zone,03} \cdot X_{CO2,in,03} \cdot MM_{CO2} \quad (604)$$

$$X_{CO2,supplyduct,ex,03} = X_{CO2,supplyduct,ex} \quad (605)$$

$$\dot{M}_{CO2,vent,04} = \dot{M}_{CO2,zone,su,04} - \dot{M}_{CO2,zone,ex,04} \quad (606)$$

$$\dot{M}_{CO2,zone,su,04} = \dot{MM}_{a,zone,04} \cdot X_{CO2,zone,su,04} \cdot MM_{CO2} \quad (607)$$

$$\dot{MM}_{a,zone,04} = \dot{M}_{a,zone,04}/MM_{dryair} \quad (608)$$

$$X_{CO2,zone,su,04} = X_{CO2,room,su,04} \quad (609)$$

$$X_{CO2,room,su,04} = \frac{\dot{M}_{a,supplyduct,ex,04} \cdot X_{CO2,supplyduct,ex,04} + \dot{M}_{a,infiltr,04} \cdot X_{CO2,out}}{\dot{M}_{a,room,04}} \quad (610)$$

$$\dot{M}_{CO2,zone,ex,04} = \dot{MM}_{a,zone,04} \cdot X_{CO2,in,04} \cdot MM_{CO2} \quad (611)$$

$$X_{CO2,supplyduct,ex,04} = X_{CO2,supplyduct,ex} \quad (612)$$

$$\dot{M}_{CO2,vent,05} = \dot{M}_{CO2,zone,su,05} - \dot{M}_{CO2,zone,ex,05} \quad (613)$$

$$\dot{M}_{CO2,zone,su,05} = \dot{MM}_{a,zone,05} \cdot X_{CO2,zone,su,05} \cdot MM_{CO2} \quad (614)$$

$$\dot{MM}_{a,zone,05} = \dot{M}_{a,zone,05}/MM_{dryair} \quad (615)$$

$$X_{CO2,zone,su,05} = X_{CO2,room,su,05} \quad (616)$$

$$X_{CO2,room,su,05} = \frac{\dot{M}_{a,supplyduct,ex,05} \cdot X_{CO2,supplyduct,ex,05} + \dot{M}_{a,infiltr,05} \cdot X_{CO2,out}}{\dot{M}_{a,room,05}} \quad (617)$$

$$\dot{M}_{CO2,zone,ex,05} = \dot{MM}_{a,zone,05} \cdot X_{CO2,in,05} \cdot MM_{CO2} \quad (618)$$

$$X_{CO2,supplyduct,ex,05} = X_{CO2,supplyduct,ex} \quad (619)$$

1.5.3 Internal CO2 production:

Outputs:

$\dot{M}_{CO2,in,0j}$

Inputs:

$f_{occ,0j}$: see §10

$$\dot{M}_{CO2,peroccupant,gh} = 40\ [\text{g/h}] \tag{620}$$

Parameters:

$n_{occ,max,0j}$: see §1.3.5

Simulation model:

$$\dot{M}_{CO2,occ,01} = f_{occ,01} \cdot \dot{M}_{CO2,occ,max,01} \tag{621}$$

$$\dot{M}_{CO2,occ,max,01} = n_{occ,max,01} \cdot \frac{\dot{M}_{CO2,peroccupant,gh}}{s/h \cdot gkg} \tag{622}$$

$$\dot{M}_{CO2,occ,02} = f_{occ,02} \cdot \dot{M}_{CO2,occ,max,02} \tag{623}$$

$$\dot{M}_{CO2,occ,max,02} = n_{occ,max,02} \cdot \frac{\dot{M}_{CO2,peroccupant,gh}}{s/h \cdot gkg} \tag{624}$$

$$\dot{M}_{CO2,occ,03} = f_{occ,03} \cdot \dot{M}_{CO2,occ,max,03} \tag{625}$$

$$\dot{M}_{CO2,occ,max,03} = n_{occ,max,03} \cdot \frac{\dot{M}_{CO2,peroccupant,gh}}{s/h \cdot gkg} \tag{626}$$

$$\dot{M}_{CO2,occ,04} = f_{occ,04} \cdot \dot{M}_{CO2,occ,max,04} \tag{627}$$

$$\dot{M}_{CO2,occ,max,04} = n_{occ,max,04} \cdot \frac{\dot{M}_{CO2,peroccupant,gh}}{s/h \cdot gkg} \tag{628}$$

$$\dot{M}_{CO2,occ,05} = f_{occ,05} \cdot \dot{M}_{CO2,occ,max,05} \tag{629}$$

$$\dot{M}_{CO2,occ,max,05} = n_{occ,max,05} \cdot \frac{\dot{M}_{CO2,peroccupant,gh}}{s/h \cdot gkg} \tag{630}$$

1.5.4 Room CO2 gain:

$$\dot{M}_{CO2,room,01} = \dot{M}_{CO2,occ,01} \tag{631}$$

$$\dot{M}_{CO2,room,02} = \dot{M}_{CO2,occ,02} \tag{632}$$

$$\dot{M}_{CO2,room,03} = \dot{M}_{CO2,occ,03} \tag{633}$$

$$\dot{M}_{CO2,room,04} = \dot{M}_{CO2,occ,04} \tag{634}$$

$$\dot{M}_{CO2,room,05} = \dot{M}_{CO2,occ,05} \tag{635}$$

1.5.5 Zone CO2 gain:

$$\dot{M}_{CO2,zone,01} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{CO2,occ,01} \tag{636}$$

$$M_{CO2,zone,01} = \int_{\tau_1}^{\tau_2} \dot{M}_{CO2,zone,01}\,\mathrm{d}\tau \quad (637)$$

$$\dot{M}_{CO2,zone,02} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{CO2,occ,02} \quad (638)$$

$$M_{CO2,zone,02} = \int_{\tau_1}^{\tau_2} \dot{M}_{CO2,zone,02}\,\mathrm{d}\tau \quad (639)$$

$$\dot{M}_{CO2,zone,03} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{CO2,occ,03} \quad (640)$$

$$M_{CO2,zone,03} = \int_{\tau_1}^{\tau_2} \dot{M}_{CO2,zone,03}\,\mathrm{d}\tau \quad (641)$$

$$\dot{M}_{CO2,zone,04} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{CO2,occ,04} \quad (642)$$

$$M_{CO2,zone,04} = \int_{\tau_1}^{\tau_2} \dot{M}_{CO2,zone,04}\,\mathrm{d}\tau \quad (643)$$

$$\dot{M}_{CO2,zone,05} = (1 - \epsilon_{occdispl}) \cdot \dot{M}_{CO2,occ,05} \quad (644)$$

$$M_{CO2,zone,05} = \int_{\tau_1}^{\tau_2} \dot{M}_{CO2,zone,05}\,\mathrm{d}\tau \quad (645)$$

——————————————————-

1.5.6 Zone CO2 balance:

$$\mathrm{d}MCO2in/\mathrm{d}tau_{01} = \dot{M}_{CO2,vent,01} + \dot{M}_{CO2,zone,01} \quad (646)$$

$$\mathrm{d}MCO2in/\mathrm{d}tau_{02} = \dot{M}_{CO2,vent,02} + \dot{M}_{CO2,zone,02} \quad (647)$$

$$\mathrm{d}MCO2in/\mathrm{d}tau_{03} = \dot{M}_{CO2,vent,03} + \dot{M}_{CO2,zone,03} \quad (648)$$

$$\mathrm{d}MCO2in/\mathrm{d}tau_{04} = \dot{M}_{CO2,vent,04} + \dot{M}_{CO2,zone,04} \quad (649)$$

$$\mathrm{d}MCO2in/\mathrm{d}tau_{05} = \dot{M}_{CO2,vent,05} + \dot{M}_{CO2,zone,05} \quad (650)$$

——————————————————-

1.5.7 CO2 concentration at room exhaust:

$$X_{CO2,room,ex,01} = \frac{\dot{M}_{a,zone,01} \cdot X_{CO2,in,01} + \left(\dot{M}_{a,room,01} - \dot{M}_{a,zone,01}\right) \cdot X_{CO2,room,su,01}}{\dot{M}_{a,room,01}} + \frac{\dot{MM}_{CO2,room,01} - \dot{MM}_{CO2,zone,01}}{\dot{MM}_{a,room,01}} \quad (65$$

with

$$\dot{MM}_{a,room,01} = \dot{M}_{a,room,01}/MM_{dryair} \quad (652)$$

$$\dot{MM}_{CO2,room,01} = \dot{M}_{CO2,room,01}/MM_{CO2} \quad (653)$$

$$\dot{MM}_{CO2,zone,01} = \dot{M}_{CO2,zone,01}/MM_{CO2} \quad (654)$$

$$X_{CO2,room,ex,02} = \frac{\dot{M}_{a,zone,02} \cdot X_{CO2,in,02} + \left(\dot{M}_{a,room,02} - \dot{M}_{a,zone,02}\right) \cdot X_{CO2,room,su,02}}{\dot{M}_{a,room,02}} + \frac{\dot{MM}_{CO2,room,02} - \dot{MM}_{CO2,zone,02}}{\dot{MM}_{a,room,02}} \quad (65$$

with

$$\dot{MM}_{a,room,02} = \dot{M}_{a,room,02}/MM_{dryair} \quad (656)$$

$$\dot{MM}_{CO2,room,02} = \dot{M}_{CO2,room,02}/MM_{CO2} \quad (657)$$

$$\dot{MM}_{CO2,zone,02} = \dot{M}_{CO2,zone,02}/MM_{CO2} \quad (658)$$

$$X_{CO2,room,ex,03} = \frac{\dot{M}_{a,zone,03} \cdot X_{CO2,in,03} + \left(\dot{M}_{a,room,03} - \dot{M}_{a,zone,03}\right) \cdot X_{CO2,room,su,03}}{\dot{M}_{a,room,03}} + \frac{\dot{MM}_{CO2,room,03} - \dot{MM}_{CO2,zone,03}}{\dot{MM}_{a,room,03}} \quad (65$$

with

$$\dot{MM}_{a,room,03} = \dot{M}_{a,room,03}/MM_{dryair} \quad (660)$$

$$\dot{MM}_{CO2,room,03} = \dot{M}_{CO2,room,03}/MM_{CO2} \quad (661)$$

$$\dot{MM}_{CO2,zone,03} = \dot{M}_{CO2,zone,03}/MM_{CO2} \quad (662)$$

$$X_{CO2,room,ex,04} = \frac{\dot{M}_{a,zone,04} \cdot X_{CO2,in,04} + \left(\dot{M}_{a,room,04} - \dot{M}_{a,zone,04}\right) \cdot X_{CO2,room,su,04}}{\dot{M}_{a,room,04}} + \frac{\dot{MM}_{CO2,room,04} - \dot{MM}_{CO2,zone,04}}{\dot{MM}_{a,room,04}} \quad (66$$

with

$$\dot{MM}_{a,room,04} = \dot{M}_{a,room,04}/MM_{dryair} \quad (664)$$

$$\dot{MM}_{CO2,room,04} = \dot{M}_{CO2,room,04}/MM_{CO2} \quad (665)$$

$$\dot{MM}_{CO2,zone,04} = \dot{M}_{CO2,zone,04}/MM_{CO2} \quad (666)$$

$$X_{CO2,room,ex,05} = \frac{\dot{M}_{a,zone,05} \cdot X_{CO2,in,05} + \left(\dot{M}_{a,room,05} - \dot{M}_{a,zone,05}\right) \cdot X_{CO2,room,su,05}}{\dot{M}_{a,room,05}} + \frac{\dot{MM}_{CO2,room,05} - \dot{MM}_{CO2,zone,05}}{\dot{MM}_{a,room,05}} \quad (66$$

with

$$\dot{MM}_{a,room,05} = \dot{M}_{a,room,05}/MM_{dryair} \quad (668)$$

$$\dot{MM}_{CO2,room,05} = \dot{M}_{CO2,room,05}/MM_{CO2} \quad (669)$$

$$\dot{MM}_{CO2,zone,05} = \dot{M}_{CO2,zone,05}/MM_{CO2} \quad (670)$$

```
$BOOKMARK 02. RETURN AIR DUCT and RETURN FAN
```

2. RETURN AIR DUCT and RETURN FAN

2.1 Return duct:

Design, selection and sizing (still to be done):

Output:

$\dot{M}_{a,returnduct,su,n}$, $D_{returnduct}$,$A_{leakage,returnduct}$,$U_{returnduct}$

Inputs:

$L_{returnduct}$

$\dot{M}_{a,ventilation,0j,n}$

Calculation:

$$\dot{M}_{a,returnduct,su,floor,n} = \dot{M}_{a,ventilation,01,n} + \dot{M}_{a,ventilation,02,n} + \dot{M}_{a,ventilation,03,n} + \dot{M}_{a,ventilation,04,n} + \dot{M}_{a,ventilation,05,n} \quad (671)$$

$$\dot{M}_{a,returnduct,su,n} = n_{floor} \cdot \dot{M}_{a,returnduct,su,floor,n} \quad (672)$$

$$\Delta p_{returnduct,n} = 130 \text{ [Pa]} \quad (673)$$

$$\dot{M}_{a,returnduct,ex,n} = \dot{M}_{a,returnduct,su,n} \quad (674)$$

(neglecting the possible infiltration)

Simulation:

Outputs:
DELTA$p_{returnduct}$, $\dot{M}_{a,returnduct,infiltr}$, $\dot{M}_{a,su,returnduct}$, $t_{a,returnduct,ex}$, $\omega_{returnduct,ex}$, $X_{CO2,returnduct,ex}$

Inputs:

$\dot{M}_{a,returnduct,su,0j}$: see § 1.2

$t_{returnduct,env}$: environment still to be defined

provisory hypotheses:

$$t_{returnduct,env} = t_{out} \quad (675)$$

$$\omega_{returnduct,env} = \omega_{out} \quad (676)$$

$$X_{CO2,returnduct,env} = X_{CO2,out} \quad (677)$$

$p_{returnduct}$

(in order to calculate the infiltration...)

$t_{a,room,ex,0j}$: see § 1.3.7

$\omega_{room,ex,0j}$: see § 1.4.7

$x_{CO2,room,ex,0j}$: see § 1.5.7

Parameters:

(coming from return duct sizing)

$D_{returnduct}$,$L_{returnduct}$,$A_{returnduct,infiltr}$,$U_{returnduct}$

Simulation model:

$$\dot{M}_{a,returnduct,su,floor} = \dot{M}_{a,returnduct,su,01} + \dot{M}_{a,returnduct,su,02} + \dot{M}_{a,returnduct,su,03} + \dot{M}_{a,returnduct,su,04} + \dot{M}_{a,returnduct,su,05} \quad (678)$$

$$\dot{M}_{a,returnduct,su} = n_{floor} \cdot \dot{M}_{a,returnduct,su,floor} \quad (679)$$

$$\dot{M}_{a,returnduct,ex,floor} = \dot{M}_{a,returnduct,su,floor} + \dot{M}_{a,returnduct,infiltr} \quad (680)$$

$$\dot{M}_{a,returnduct,infiltr} = 0 \quad (681)$$

if the infiltration is neglected

$$\dot{M}_{a,returnduct,ex} = n_{floor} \cdot \dot{M}_{a,returnduct,ex,floor} \tag{682}$$

$$t_{a,returnduct,su} = \frac{\dot{M}_{a,returnduct,su,01} \cdot t_{a,room,ex,01} + \dot{M}_{a,returnduct,su,02} \cdot t_{a,room,ex,02} + \dot{M}_{a,returnduct,su,03} \cdot t_{a,room,ex,03} + \dot{M}_{a,retur}}{\dot{M}_{a,returnduct,su,floor}}$$

$$\omega_{returnduct,su} = \frac{\dot{M}_{a,returnduct,su,01} \cdot \omega_{room,ex,01} + \dot{M}_{a,returnduct,su,02} \cdot \omega_{room,ex,02} + \dot{M}_{a,returnduct,su,03} \cdot \omega_{room,ex,03} + \dot{M}_{a,returnduc}}{\dot{M}_{a,returnduct,su,floor}}$$

$$X_{CO2,returnduct,su} = \frac{\dot{M}_{a,returnduct,su,01} \cdot X_{CO2,room,ex,01} + \dot{M}_{a,returnduct,su,02} \cdot X_{CO2,room,ex,02} + \dot{M}_{a,returnduct,su,03} \cdot X_{CO2,room,}}{\dot{M}_{a,returnduct,su,floor}}$$

$$\Delta p_{returnduct} = \Delta p_{returnduct,n} \cdot \left(\dot{M}_{a,returnduct,su} / \dot{M}_{a,returnduct,su,n}\right)^2 \tag{686}$$

$$t_{a,returnduct,ex} = t_{a,returnduct,su} \tag{687}$$

(if both heat exchange and mixing with infiltration are neglected)

$$\omega_{returnduct,ex} = \omega_{returnduct,su} \tag{688}$$

(if both condensation along the duct and mixing with infiltration are neglected)

$$X_{CO2,returnduct,ex} = X_{CO2,returnduct,su} \tag{689}$$

(if mixing with infiltration is neglected)

———————————————-

2.2 Return fan:

Selection and sizing (still to be done):

$$\dot{M}_{a,returnfan,n} = \dot{M}_{a,returnduct,ex,n} \tag{690}$$

$$\Delta p_{returnfan,n} = \Delta p_{returnduct,n} + \Delta p_{return,econo,n} + \Delta p_{return,recovery,n} \tag{691}$$

$$\epsilon_{s,returnfan,n} = 0.6 \tag{692}$$

(see characteristics of selected fan)

————————

Simulation

Outputs:

$\dot{W}_{returnfan}$, $t_{a,returnfan,ex}$, $\omega_{returnfan,ex}$, $X_{CO2,returnfan,ex}$

Inputs:

$t_{a,returnduct,ex}$: see § 2.1

$\omega_{returnduct,ex}$: see § 2.1

$X_{CO2,returnduct,ex}$: see § 2.1

$\Delta p_{returnduct}$**: see § 2.1**

$\Delta p_{return,econo}$: see § 3.1

$\Delta p_{return,recovery}$: see § 3.0

Parameter:

$\epsilon_{s,returnfan,n}$

(coming from sizing)

Simulation model:

$$\dot{M}_{a,returnfan} = \dot{M}_{a,returnduct,ex} \tag{693}$$

$$t_{a,returnfan,su} = t_{a,returnduct,ex} \tag{694}$$

$$\omega_{returnfan,su} = \omega_{returnduct,ex} \tag{695}$$

$$X_{CO2,returnfan,su} = X_{CO2,returnduct,ex} \tag{696}$$

$$\Delta p_{returnfan} = \Delta p_{returnduct} + \Delta p_{return,econo} + \Delta p_{return,recovery} \tag{697}$$

$$\epsilon_{s,returnfan} = \epsilon_{s,returnfan,n} \tag{698}$$

(might be also identified from fan characteristics)

$$\dot{W}_{returnfan} = f_{returnfan} \cdot \dot{V}_{a,returnfan} \cdot \frac{\Delta p_{returnfan}}{\epsilon_{s,returnfan}} \tag{699}$$

$$\dot{V}_{a,returnfan} = \dot{M}_{a,returnfan} \cdot v_a \tag{700}$$

$$W_{returnfan} = \int_{\tau_1}^{\tau_2} \dot{W}_{returnfan} \, \mathrm{d}\tau \tag{701}$$

$$W_{returnfan,kWh} = W_{returnfan}/J/kWh \tag{702}$$

$$t_{a,returnfan,ex} = t_{a,returnfan,su} + \frac{\dot{W}_{returnfan}}{\dot{M}_{a,returnfan} \cdot c_{p,ref} + Watt/Kelvin_{min}} \tag{703}$$

(in fair approximation and if the motor is inside the fan box)

$$\omega_{returnfan,ex} = \omega_{returnfan,su} \tag{704}$$

$$X_{CO2,returnfan,ex} = X_{CO2,returnfan,su} \tag{705}$$

`$BOOKMARK 03. AIR HANDLING UNIT`

3. AIR HANDLING UNIT

Overall sizing: still to be done

3.0. Heat recovery:

Sizing: still to be done

$$\dot{M}_{a,recovery,n} = \dot{M}_{a,returnfan,n} \tag{706}$$

(without any recirculation in nominal conditions)

$$\Delta p_{fresh,recovery,n} = 230 \;\; [\mathrm{Pa}] \tag{707}$$

(including filter)

$$\Delta p_{return,recovery,n} = 230 \;\; [\mathrm{Pa}] \tag{708}$$

(NB: would be very different if using a loop with two coils or another device as, for example, a rotating recovery)

$$\epsilon_{recovery,n} = 0.7 \;\; [\,] \tag{709}$$

$$\dot{W}_{recovery,n} = 0 \;\; [\mathrm{W}] \tag{710}$$

(if no electrical motor included)

Simulation model:

Outputs:

$t_{a,recovery,ex}$, $\omega_{recovery,ex}$, $X_{CO2,recovery,ex}$, $\Delta p_{recovery}$, $\dot{W}_{recovery}$

Inputs:

$\dot{M}_{a,fresh,econo}$: see § 3.1

Provisory input:

t_{out}, ω_{out}, $X_{CO2,out}$: see § 9

$t_{a,returnfan,ex}$, $\omega_{returnfan,ex}$, $X_{CO2,returnfan,ex}$: outputs of § 2.2

$f_{recovery}$: see § 10

Parameters:

$\Delta p_{fresh,recovery,n}$, $\Delta p_{return,recovery,n}$ and $\epsilon_{recovery,n}$ and $\dot{W}_{recovery,n}$ coming from sizing

Simulation model:

$$\dot{M}_{a,recovery} = \dot{M}_{a,fresh,econo} \tag{711}$$

$$\epsilon_{recovery} = \epsilon_{recovery,n} \tag{712}$$

(in first and very crude approximation; it should vary with both air flow rates!)

$$t_{a,recovery,ex} = t_{out} + f_{recovery} \cdot \epsilon_{recovery} \cdot (t_{a,returnfan,ex} - t_{out}) \tag{713}$$

$$\omega_{recovery,ex} = \omega_{out} \tag{714}$$

$$X_{CO2,recovery,ex} = X_{CO2,out} \tag{715}$$

$$\Delta p_{fresh,recovery} = \Delta p_{fresh,recovery,n} \cdot \left(\dot{M}_{a,recovery}/\dot{M}_{a,recovery,n}\right)^2 \tag{716}$$

$$\Delta p_{return,recovery} = \Delta p_{return,recovery,n} \cdot \left(\dot{M}_{a,recovery}/\dot{M}_{a,recovery,n}\right)^2 \tag{717}$$

(if turbulent regimes on both sides)

$$\dot{W}_{recovery} = f_{recovery} \cdot \dot{W}_{recovery,n} \tag{718}$$

$$W_{recovery} = \int_{\tau_1}^{\tau_2} \dot{W}_{recovery}\,\mathrm{d}\tau \tag{719}$$

$$W_{recovery,kWh} = W_{recovery}/J/kWh \tag{720}$$

3.1 Economizer

Sizing still to be done

$$\Delta p_{return,econo,n} = 0 \ \text{[Pa]} \tag{721}$$

$$\Delta p_{fresh,econo,n} = 0 \ \text{[Pa]} \tag{722}$$

(if there is no economizer!)

Simulation

Outputs:

$t_{a,econo,ex}$, $\omega_{econo,ex}$, $X_{CO2,econo,ex}$, $\Delta p_{fresh,econo}$

Inputs:

$\dot{M}_{a,returnfan}$, $t_{a,returnfan,ex}$, $\omega_{returnfan,ex}$ and $X_{CO2,returnfan,ex}$: see § 2.2

$t_{a,recovery,ex}$, $\omega_{recovery,ex}$ and $X_{CO2,recovery,ex}$: see § 3.0

$\dot{M}_{a,mainfan}$: see § 3.7

Control variable to be tuned for air quality and/or for free cooling:

$X_{fresh,econo}$: see § 10

($X_{fresh,econo}$=1 [-] if no economizer or no use of it)

Parameters:

Louvers characteristics coming from sizing...

Simulation model:

$$\dot{M}_{a,return,econo} = \dot{M}_{a,returnfan} \tag{723}$$

$$\dot{M}_{a,econo,ex} = \dot{M}_{a,mainfan} \tag{724}$$

(if neglecting AHU leakage)

$$\dot{M}_{a,fresh,econo} = X_{fresh,econo} \cdot \dot{M}_{a,econo,ex} \tag{725}$$

(with $X_{fresh,econo}$=1, if there is no economizer)

$$\Delta p_{return,econo} = \Delta p_{return,econo,n} \tag{726}$$

$$\Delta p_{fresh,econo} = \Delta p_{fresh,econo,n} \tag{727}$$

$$t_{a,return,econo} = t_{a,returnfan,ex} \tag{728}$$

(if there is an economizer, these pressure drops should be calculated as function of corresponding flow rates)

$$\omega_{return,econo} = \omega_{returnfan,ex} \tag{729}$$

$$X_{CO2,return,econo} = X_{CO2,returnfan,ex} \tag{730}$$

$$t_{a,fresh,econo,su} = t_{a,recovery,ex} \tag{731}$$

$$\omega_{fresh,econo,su} = \omega_{recovery,ex} \tag{732}$$

$$X_{CO2,fresh,econo,su} = X_{CO2,recovery,ex} \tag{733}$$

$$t_{a,econo,ex} = \frac{\left(\dot{M}_{a,econo,ex} - \dot{M}_{a,fresh,econo}\right) \cdot t_{a,return,econo} + \dot{M}_{a,fresh,econo} \cdot t_{a,fresh,econo,su}}{\dot{M}_{a,econo,ex} + \dot{M}_{min}} \tag{734}$$

$$\omega_{econo,ex} = \frac{\left(\dot{M}_{a,econo,ex} - \dot{M}_{a,fresh,econo}\right) \cdot \omega_{return,econo} + \dot{M}_{a,fresh,econo} \cdot \omega_{fresh,econo,su}}{\dot{M}_{a,econo,ex} + \dot{M}_{min}} \tag{735}$$

$$X_{CO2,econo,ex} = \frac{\left(\dot{M}_{a,econo,ex} - \dot{M}_{a,fresh,econo}\right) \cdot X_{CO2,return,econo} + \dot{M}_{a,fresh,econo} \cdot X_{CO2,fresh,econo,su}}{\dot{M}_{a,econo,ex} + \dot{M}_{min}} \tag{736}$$

3.2 AHU filter

(NB: Other filters of the HVAC system should also be taken into account)

Selection and sizing (still to be done):

$$\dot{M}_{a,filter,n} = \dot{M}_{a,mainfan,n} \tag{737}$$

$$\delta p_{filter,n} = 150 \text{ [Pa]} \tag{738}$$

Simulation:

Outputs:

Air quality, $t_{a,filter,ex}$, $\omega_{filter,ex}$, $X_{CO2,filter,ex}$ and Δp_{filter}

Inputs:

$\dot{M}_{a,econo,ex}$, $t_{a,econo,ex}$, $\omega_{econo,ex}$ and $X_{CO2,econo,ex}$

fouling (function of building occupancy, running time and maintenance)

Parameters:

Effectiveness and pressure drop coming from selection and sizing...

Simulation model:

$$\dot{M}_{a,filter} = \dot{M}_{a,mainfan} \tag{739}$$

$$t_{a,filter,su} = t_{a,econo,ex} \tag{740}$$

$$\omega_{filter,su} = \omega_{econo,ex} \tag{741}$$

$$X_{CO2,filter,su} = X_{CO2,econo,ex} \tag{742}$$

$$t_{a,filter,ex} = t_{a,filter,su} \tag{743}$$

$$\omega_{filter,ex} = \omega_{filter,su} \tag{744}$$

$$X_{CO2,filter,ex} = X_{CO2,filter,su} \tag{745}$$

$$\Delta p_{filter} = \Delta p_{filter,n} \cdot \dot{M}_{a,filter} / \dot{M}_{a,filter,n} \tag{746}$$

(should be calculated with taking into account of the fouling effect...)

3.3 Pre-heating coil

Selection and sizing:

Sizing data:

Output:

$\dot{Q}_{preheatingcoil,n}$, $\dot{M}_{w,preheatingcoil,n}$, $\epsilon_{preheatingcoil,n}$

Inputs:

$$t_{w,preheatingcoil,su,n} = 70 \ [°\mathrm{C}] \tag{747}$$

$$t_{w,preheatingcoil,ex,n} = 50 \ [°\mathrm{C}] \tag{748}$$

$$t_{a,preheatingcoil,su,n} = -10 \ [°\mathrm{C}] \tag{749}$$

(or a higher temperature thanks to heat recovery)

$$RH_{preheatingcoil,su,n} = 0.95 \ [-] \tag{750}$$

$$t_{a,adiabhum,ex,n} = 12 \ [\mathrm{C}] \tag{751}$$

$$RH_{adiabhum,ex,n} = 0.95 \ [-] \tag{752}$$

Calculation:

$$\dot{M}_{a,preheatingcoil,n} = \dot{M}_{a,mainfan,n} \tag{753}$$

$$p_{w,s,preheatingcoil,su,n}/pascal = \exp\left(\left(A \cdot \frac{t_{a,preheatingcoil,su,n}/Celsius}{B + t_{a,preheatingcoil,su,n}/Celsius}\right) + C\right) \tag{754}$$

$$p_{w,preheatingcoil,su,n} = RH_{preheatingcoil,su,n} \cdot p_{w,s,preheatingcoil,su,n} \tag{755}$$

$$\omega_{preheatingcoil,su,n} = 0.622 \cdot \frac{p_{w,preheatingcoil,su,n}}{p_{ref} - p_{w,preheatingcoil,su,n}} \tag{756}$$

$$\omega_{preheatingcoil,ex,n} = \omega_{preheatingcoil,su,n} \tag{757}$$

$$h_{a,preheatingcoil,su,n} = c_{p,a} \cdot t_{a,preheatingcoil,su,n} + \omega_{preheatingcoil,su,n} \cdot (c_{p,g} \cdot t_{a,preheatingcoil,su,n} + h_{fg,0}) \tag{758}$$

$$p_{w,s,adiabhum,ex,n}/pascal = \exp\left(\left(A \cdot \frac{t_{a,adiabhum,ex,n}/Celsius}{B + t_{a,adiabhum,ex,n}/Celsius}\right) + C\right) \tag{759}$$

$$p_{w,adiabhum,ex,n} = RH_{adiabhum,ex,n} \cdot p_{w,s,adiabhum,ex,n} \tag{760}$$

$$\omega_{adiabhum,ex,n} = 0.622 \cdot \frac{p_{w,adiabhum,ex,n}}{p_{ref} - p_{w,adiabhum,ex,n}} \tag{761}$$

$$h_{a,adiabhum,ex,n} = c_{p,a} \cdot t_{a,adiabhum,ex,n} + \omega_{adiabhum,ex,n} \cdot (c_{p,g} \cdot t_{a,adiabhum,ex,n} + h_{fg,0}) \tag{762}$$

$$h_{a,preheatingcoil,ex,n} = h_{a,adiabhum,ex,n} \tag{763}$$

(in fair approximation)

$$h_{a,preheatingcoil,ex,n} = c_{p,a} \cdot t_{a,preheatingcoil,ex,n} + \omega_{preheatingcoil,ex,n} \cdot (c_{p,g} \cdot t_{a,preheatingcoil,ex,n} + h_{fg,0}) \tag{764}$$

(this equation is defining the temperature)

$$\dot{Q}_{preheatingcoil,n} = \dot{M}_{a,preheatingcoil,n} \cdot (h_{a,preheatingcoil,ex,n} - h_{a,preheatingcoil,su,n}) \tag{765}$$

$$\dot{M}_{w,preheatingcoil,n} = \frac{\dot{Q}_{preheatingcoil,n}}{c_f \cdot (t_{w,preheatingcoil,su,n} - t_{w,preheatingcoil,ex,n})} \tag{766}$$

$$\epsilon_{preheatingcoil,n} = \frac{t_{a,preheatingcoil,ex,n} - t_{a,preheatingcoil,su,n}}{t_{w,preheatingcoil,su,n} - t_{a,preheatingcoil,su,n}} \tag{767}$$

Water pump associated to the pre-heating coil:

$$\dot{W}_{preheating,n} = 0.002 \cdot \dot{Q}_{preheatingcoil,n} \tag{768}$$

(very provisory and questionable estimate; should depends from actual temperatures and corresponding water flow rate)

Nominal pressure drop on air side:

$$\Delta p_{preheatingcoil,n} = 80 \ \text{[Pa]} \tag{769}$$

(also provisory estimate; depends on coil selection)

Simulation model

Outputs:

$X_{preheatingcoilcontrol}$, $t_{a,preheatingcoil,ex}$, $\omega_{preheatingcoil,ex}$, $X_{CO2,preheatingcoil,ex}$, air side pressure drop, $\dot{Q}_{preheatingcoil}$, $t_{w,preheatingcoil,ex}$, water side pressure drop

Inputs:

$\dot{M}_{a,mainfan}$

$t_{a,filter,ex}$

$\omega_{filter,ex}$

$X_{CO2,filter,ex}$

$t_{hotopenheader,sec,ex}$

see § 6.1

Control inputs:

$t_{a,adiabhum,ex,set}$: see § 10

$f_{preheatingcoil}$: see § 10

(pre$_{heating}$ coil hot water supply)

$f_{preheatingpump}$: see § 10

Parameters:

$\epsilon_{a,preheatingcoil,n}$

$\mathrm{RH}_{adiabhum,ex,n}$

Simulation model:

$$t_{w,preheatingcoilloop,su} = t_{hotopenheader,sec,ex} \quad (770)$$

(if neglecting the piping heat loss)

$$\dot{M}_{w,preheatingcoil} = \dot{M}_{w,preheatingcoil,n} \quad (771)$$

$$\dot{M}_{a,preheatingcoil} = \dot{M}_{a,mainfan} \quad (772)$$

$$t_{a,preheatingcoil,su} = t_{a,filter,ex} \quad (773)$$

$$\omega_{preheatingcoil,su} = \omega_{filter,ex} \quad (774)$$

$$X_{CO2,preheatingcoil,su} = X_{CO2,filter,ex} \quad (775)$$

$$\omega_{preheatingcoil,ex} = \omega_{preheatingcoil,su} \quad (776)$$

$$X_{CO2,preheatingcoil,ex} = X_{CO2,preheatingcoil,su} \quad (777)$$

$$h_{a,preheatingcoil,su} = c_{p,a} \cdot t_{a,preheatingcoil,su} + \omega_{preheatingcoil,su} \cdot (c_{p,g} \cdot t_{a,preheatingcoil,su} + h_{fg,0}) \quad (778)$$

Definition of the air status at adiabatic humidifier exhaust, if used:

$$p_{w,s,adiabhum,ex,set}/pascal = \exp\left(\left(A \cdot \frac{t_{a,adiabhum,ex,set}/Celsius}{B + t_{a,adiabhum,ex,set}/Celsius}\right) + C\right) \quad (779)$$

$$p_{w,adiabhum,ex,set} = RH_{adiabhum,ex,n} \cdot p_{w,s,adiabhum,ex,set} \quad (780)$$

$$\omega_{adiabhum,ex,set} = 0.622 \cdot \frac{p_{w,adiabhum,ex,set}}{p_{ref} - p_{w,adiabhum,ex,set}} \quad (781)$$

$$h_{a,adiabhum,ex,set} = c_{p,a} \cdot t_{a,adiabhum,ex,set} + \omega_{adiabhum,ex,set} \cdot (c_{p,g} \cdot t_{a,adiabhum,ex,set} + h_{fg,0}) \quad (782)$$

The following two equations have also to be used in case of adiabatic humidification

$$h_{a,preheatingcoil,ex,set} = h_{a,adiabhum,ex,set} \quad (783)$$

(in fair approximation)

$$h_{a,preheatingcoil,ex,set} = c_{p,a} \cdot t_{a,preheatingcoil,ex,set} + \omega_{preheatingcoil,ex} \cdot (c_{p,g} \cdot t_{a,preheatingcoil,ex,set} + h_{fg,0}) \quad (784)$$

(this equation is defining the temperature set point)

If no adiabatic humidification, the set point can be arbitrarily fixed:

$\mathbf{t}_{a,preheatingcoil,ex,set}$: see § 10

And, if perfect control, then,

$$t_{a,preheatingcoil,ex,ON} = \max\left(t_{a,preheatingcoil,su},\ t_{a,preheatingcoil,ex,set}\right) \quad (785)$$

$$t_{a,preheatingcoil,ex} = \mathrm{If}(f_{preheatingcoil},\ 1,\ t_{a,preheatingcoil,su},\ t_{a,preheatingcoil,ex,ON},\ t_{a,preheatingcoil,ex,ON}) \quad (786)$$

$$h_{a,preheatingcoil,ex} = c_{p,a} \cdot t_{a,preheatingcoil,ex} + \omega_{preheatingcoil,ex} \cdot (c_{p,g} \cdot t_{a,preheatingcoil,ex} + h_{fg,0}) \quad (787)$$

$$\dot{Q}_{preheatingcoil} = \dot{M}_{a,preheatingcoil} \cdot (h_{a,preheatingcoil,ex} - h_{a,preheatingcoil,su}) \quad (788)$$

$$\epsilon_{preheatingcoil} = \epsilon_{preheatingcoil,n} \quad (789)$$

(if constant air and water flow rates)

$$t_{w,preheatingcoil,su} = t_{a,preheatingcoil,su} + \frac{t_{a,preheatingcoil,ex} - t_{a,preheatingcoil,su}}{\epsilon_{preheatingcoil}} \quad (790)$$

(this is the temperature required at coil supply, not the actual temperature at pre$_{heating}$ coil loop supply! it will become a set point or an ideal value!)

$$t_{w,preheatingcoil,ex} = t_{w,preheatingcoil,su} - \frac{\dot{Q}_{preheatingcoil}}{\dot{M}_{w,preheatingcoil} \cdot c_f + Watt/Kelvin_{min}} \quad (791)$$

$$t_{w,preheatingcoilloop,ex} = t_{w,preheatingcoil,ex} \quad (792)$$

$$\dot{M}_{w,preheatingloop,su} = \frac{\dot{Q}_{preheatingcoil} - \dot{W}_{preheatingpump}}{(c_f \cdot (t_{w,preheatingcoilloop,su} - t_{w,preheatingcoilloop,ex}) + J/kg_{min})} \quad (793)$$

Control variable:

$$X_{preheatingcoil} = \frac{\dot{M}_{w,preheatingloop,su}}{\dot{M}_{w,preheatingcoil} + 0.0001} \quad (794)$$

Heat emission:

$$Q_{preheatingcoil} = \int_{\tau_1}^{\tau_2} \dot{Q}_{preheatingcoil} \, \mathrm{d}\tau \quad (795)$$

$$Q_{preheatingcoil,kWh} = Q_{preheatingcoil}/J/kWh \quad (796)$$

Electrical consumption:

$$\dot{W}_{preheating} = f_{preheatingpump} \cdot \dot{W}_{preheating,n} \quad (797)$$

$$W_{preheating} = \int_{\tau_1}^{\tau_2} \dot{W}_{preheating} \, \mathrm{d}\tau \quad (798)$$

$$W_{preheating,kWh} = W_{preheating}/J/kWh \quad (799)$$

Air side pressure drop:

$$\Delta p_{preheatingcoil} = \Delta p_{preheatingcoil,n} \cdot \dot{M}_{a,preheatingcoil}/\dot{M}_{a,preheatingcoil,n} \quad (800)$$

3.4 Adiabatic humidifier

Sizing

$$\dot{M}_{a,adiabhum,n} = \dot{M}_{a,mainfan,n} \quad (801)$$

$$\Delta p_{adiabhum,n} = 200 \text{ [Pa]} \quad (802)$$

—-

Simulation model:

Outputs:

$t_{a,adiabhum,ex}$, $\omega_{adiabhum,ex}$, $X_{CO2,adiabhum,ex}$

Inputs:

$\dot{M}_{a,preheatingcoil}$

$t_{a,preheatingcoil,ex}$

$\omega_{preheatingcoil,ex}$

$X_{CO2,preheatingcoil,ex}$

$f_{adiabhum}$: see § 10

$$t_{w,adiabhum,su} = 20 \ [\mathrm{C}] \tag{803}$$

$t_{a,adiabhum,ex,set}$

$\omega_{adiabhum,ex,set}$

Simulation:

$$t_{a,adiabhum,su} = t_{a,preheatingcoil,ex} \tag{804}$$

$$\omega_{adiabhum,su} = \omega_{preheatingcoil,ex} \tag{805}$$

$$X_{CO2,adiabhum,su} = X_{CO2,preheatingcoil,ex} \tag{806}$$

and, if used and if perfect control,

$$t_{a,adiabhum,ex,ON} = t_{a,adiabhum,ex,set} \tag{807}$$

$$\omega_{adiabhum,ex,ON} = \omega_{adiabhum,ex,set} \tag{808}$$

$$t_{a,adiabhum,ex} = \mathbf{If}(f_{adiabhum},\ 1,\ t_{a,adiabhum,su},\ t_{a,adiabhum,ex,ON},\ t_{a,adiabhum,ex,ON}) \tag{809}$$

$$\omega_{adiabhum,ex} = \mathbf{If}(f_{adiabhum},\ 1,\ \omega_{adiabhum,su},\ \omega_{adiabhum,ex,ON},\ \omega_{adiabhum,ex,ON}) \tag{810}$$

and, if not used:

$t_{a,adiabhum,ex}$=$t_{a,adiabhum,su}$
omega$_{adiabhum,ex}$=$\omega_{adiabhum,su}$

$$X_{CO2,adiabhum,ex} = X_{CO2,adiabhum,su} \tag{811}$$

$$\dot{M}_{a,adiabhum} = \dot{M}_{a,mainfan} \tag{812}$$

Water consumption:

$$\dot{M}_{w,adiabhum} = \dot{M}_{a,adiabhum} \cdot (\omega_{adiabhum,ex} - \omega_{adiabhum,su}) \tag{813}$$

$$M_{w,adiabhum} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,adiabhum}\, \mathrm{d}\tau \tag{814}$$

Air side pressure drop:

$$\Delta p_{adiabhum} = \Delta p_{adiabhum,n} \cdot \dot{M}_{a,adiabhum} / \dot{M}_{a,adiabhum,n} \tag{815}$$

3.5 Cooling coil

Selection and sizing:

Sizing data:

Output:

$\dot{Q}_{coolingcoil,n}$, $\dot{M}_{w,coolingcoil,n}$, $\mathrm{AU}_{c,coolingcoil}$, $\mathrm{AU}_{c,w,coolingcoil,n}$

Inputs:

$$t_{w,coolingcoil,su,n} = 7 \ [\mathrm{C}] \tag{816}$$

$$t_{w,coolingcoil,ex,n} = 12 \ [\mathrm{C}] \tag{817}$$

$$t_{a,coolingcoil,su,n} = 30 \ [\mathrm{C}] \tag{818}$$

$$RH_{coolingcoil,su,n} = 0.7 \ [-] \tag{819}$$

$\dot{M}_{a,mainfan,n}$

$$t_{a,coolingcoil,ex,n} = 12 \ [\mathrm{C}] \tag{820}$$

$$\epsilon_{c,coolingcoil,n} = 0.9 \ [-] \tag{821}$$

Calculation:

$$\dot{M}_{a,coolingcoil,n} = \dot{M}_{a,mainfan,n} \tag{822}$$

$$p_{w,s,coolingcoil,su,n}/pascal = \exp\left(\left(A \cdot \frac{t_{a,coolingcoil,su,n}/Celsius}{B + t_{a,coolingcoil,su,n}/Celsius}\right) + C\right) \tag{823}$$

$$p_{w,coolingcoil,su,n} = RH_{coolingcoil,su,n} \cdot p_{w,s,coolingcoil,su,n} \tag{824}$$

$$\omega_{coolingcoil,su,n} = 0.622 \cdot \frac{p_{w,coolingcoil,su,n}}{p_{ref} - p_{w,coolingcoil,su,n}} \tag{825}$$

$$h_{a,coolingcoil,su,n} = c_{p,a} \cdot t_{a,coolingcoil,su,n} + \omega_{coolingcoil,su,n} \cdot (c_{p,g} \cdot t_{a,coolingcoil,su,n} + h_{fg,0}) \tag{826}$$

air side effectiveness:

$$\epsilon_{c,coolingcoil,n} = \frac{t_{a,coolingcoil,su,n} - t_{a,coolingcoil,ex,n}}{t_{a,coolingcoil,su,n} - t_{c,coolingcoil,n}} \tag{827}$$

$$\epsilon_{c,coolingcoil,n} = \frac{\omega_{coolingcoil,su,n} - \omega_{coolingcoil,ex,n}}{\omega_{coolingcoil,su,n} - \omega_{c,coolingcoil,n}} \tag{828}$$

$$\omega_{c,coolingcoil,n} = D0 + D1 \cdot T_{c,coolingcoil,n}/Celsius + D2 \cdot (T_{c,coolingcoil,n}/Celsius)^2 \tag{829}$$

$\epsilon_{c,coolingcoil,n}$=(1-exp(-$\mathrm{NTU}_{c,coolingcoil,n}$))
$\mathrm{NTU}_{c,coolingcoil,n}$=$\mathrm{AU}_{c,coolingcoil,n}$/($\dot{M}_{a,coolingcoil,n}$*($c_{p,a}$+$\omega_{ref}$*$c_{p,g}$))

water side effectiveness:

$$\epsilon_{c,w,coolingcoil,n} = \frac{t_{w,coolingcoil,ex,n} - t_{w,coolingcoil,su,n}}{t_{c,coolingcoil,n} - t_{w,coolingcoil,su,n}} \tag{830}$$

$$h_{a,coolingcoil,ex,n} = c_{p,a} \cdot t_{a,coolingcoil,ex,n} + \omega_{coolingcoil,ex,n} \cdot (c_{p,g} \cdot t_{a,coolingcoil,ex,n} + h_{fg,0}) \quad (831)$$

$$\dot{Q}_{coolingcoil,n} = \dot{M}_{a,coolingcoil,n} \cdot (h_{a,coolingcoil,su,n} - h_{a,coolingcoil,ex,n}) \quad (832)$$

$$\dot{M}_{w,coolingcoil,n} = \frac{\dot{Q}_{coolingcoil,n}}{c_f \cdot (t_{w,coolingcoil,ex,n} - t_{w,coolingcoil,su,n})} \quad (833)$$

$\epsilon_{c,w,coolingcoil,n}$=(1-exp(-NTU$_{c,w,coolingcoil,n}$))
NTU$_{c,w,coolingcoil,n}$=AU$_{c,w,coolingcoil,n}$/($\dot{M}_{w,coolingcoil,n}$*c$_f$)

$$\Delta p_{coolingcoil,n} = 140 \text{ [Pa]} \quad (834)$$

Simulation model:

Outputs:

X$_{coolingcoilcontrol}$, t$_{a,coolingcoil,ex}$, $\omega_{coolingcoil,ex}$, X$_{CO2,coolingcoil,ex}$, air side pressure drop, $\dot{Q}_{coolingcoil}$, $\dot{M}_{w,condensated}$, water side pressure drop

Inputs:

$\dot{M}_{a,mainfan}$

t$_{a,adiabhum,ex}$

$\omega_{adiabhum,ex}$

X$_{CO2,adiabhum,ex}$

t$_{coldopenheader,sec,ex}$

see § 6.1

Control input:

t$_{a,coolingcoil,ex,set}$: see § 10

f$_{coolingcoil}$: see § 10

Parameters:

$\dot{M}_{a,coolingcoil,n}$

AU$_{c,coolingcoil,n}$

$\dot{M}_{w,coolingcoil,n}$

AU$_{c,w,coolingcoil,n}$

Simulation model:

$$t_{w,coolingcoil,su} = t_{coldopenheader,sec,ex} + \frac{\dot{W}_{coolingcoilpump}}{c_f \cdot \dot{M}_{w,coolingcoilcircuit}} \quad (835)$$

(if neglecting the piping heat gain)

$$t_{a,coolingcoil,su} = t_{a,adiabhum,ex} \quad (836)$$

$$\omega_{coolingcoil,su} = \omega_{adiabhum,ex} \quad (837)$$

$$X_{CO2,coolingcoil,su} = X_{CO2,adiabhum,ex} \quad (838)$$

$$X_{CO2,coolingcoil,ex} = X_{CO2,coolingcoil,su} \quad (839)$$

$$t_{a,coolingcoil,ex} = \textbf{If}(f_{coolingcoil},\ 1,\ t_{a,coolingcoil,su},\ t_{a,coolingcoil,ex,ON},\ t_{a,coolingcoil,ex,ON}) \quad (840)$$

$$t_{a,coolingcoil,ex,ON} = \min\left(t_{a,coolingcoil,su},\ t_{a,coolingcoil,ex,set}\right) \quad (841)$$

(if perfect control)

$$\dot{M}_{a,coolingcoil} = \dot{M}_{a,mainfan} \quad (842)$$

If varying very much the air flow rate, then:

AU$_{c,coolingcoil}$=AU$_{c,coolingcoil,n}$*($\dot{M}_{a,coolingcoil}$/$\dot{M}_{a,coolingcoil,n}$)$^{0.6}$ NTU$_{c,coolingcoil}$=AU$_{c,coolingcoil}$/($\dot{M}_{a,coolingcoil}$*(c$_{p,a}$+ω_{ref}*c$_{p,g}$))
epsilon$_{c,coolingcoil}$=(1-exp(-NTU$_{c,coolingcoil}$))

and if almost the same air flow rate, then:

$$\epsilon_{c,coolingcoil} = \epsilon_{c,coolingcoil,n} \quad (843)$$

Identification of the contact temperature:

$$t_{c,coolingcoil} = t_{a,coolingcoil,su} - \frac{t_{a,coolingcoil,su} - t_{a,coolingcoil,ex}}{\epsilon_{c,coolingcoil}} \quad (844)$$

Contact humidity ratio:

$$\omega_{c,coolingcoil} = D0 + D1 \cdot T_{c,coolingcoil}/Celsius + D2 \cdot (T_{c,coolingcoil}/Celsius)^2 \quad (845)$$

Exhaust air humidity ratio in wet regime:

$$\omega_{coolingcoilwet,ex} = \omega_{coolingcoil,su} - \epsilon_{c,coolingcoil} \cdot (\omega_{coolingcoil,su} - \omega_{c,coolingcoil}) \quad (846)$$

and actually:

$$\omega_{coolingcoil,ex} = \min\left(\omega_{coolingcoil,su},\ \omega_{coolingcoilwet,ex}\right) \quad (847)$$

Supply and exhaust enthalpies:

$$h_{a,coolingcoil,su} = c_{p,a} \cdot t_{a,coolingcoil,su} + \omega_{coolingcoil,su} \cdot (c_{p,g} \cdot t_{a,coolingcoil,su} + h_{fg,0}) \quad (848)$$

$$h_{a,coolingcoil,ex} = c_{p,a} \cdot t_{a,coolingcoil,ex} + \omega_{coolingcoil,ex} \cdot (c_{p,g} \cdot t_{a,coolingcoil,ex} + h_{fg,0}) \quad (849)$$

Cooling power:

$$\dot{Q}_{coolingcoil} = \dot{M}_{a,coolingcoil} \cdot (h_{a,coolingcoil,su} - h_{a,coolingcoil,ex}) \quad (850)$$

Cooling energy:

$$Q_{coolingcoil} = \int_{\tau_1}^{\tau_2} \dot{Q}_{coolingcoil}\ \mathrm{d}\tau \quad (851)$$

$$Q_{coolingcoil,kWh} = Q_{coolingcoil}/J/kWh \quad (852)$$

Determination of the cooling water flow rate:

$$\dot{Q}_{coolingcoil} = \epsilon_{c,w,coolingcoil} \cdot \dot{M}_{w,coolingcoil} \cdot c_f \cdot (t_{c,coolingcoil} - t_{w,coolingcoil,su}) \quad (853)$$

Determination of cooling coil exhaust water temperature

$$t_{w,coolingcoil,ex} = t_{w,coolingcoil,su} + \left(\frac{\dot{Q}_{Coolingcoil}}{c_f \cdot \dot{M}_{w,Coolingcoilcircuit}} \right) \tag{854}$$

Simplified law of variation of the water side effectiveness:

$$\epsilon_{c,w,coolingcoil} = (\epsilon_{c,w,coolingcoil,n} - 1) \cdot \dot{M}_{w,coolingcoil} / \dot{M}_{w,coolingcoil,n} + 1 \tag{855}$$

$\epsilon_{c,w,coolingcoil}$=$\epsilon_{c,w,coolingcoil,n}$

Water flow rate ratio:

X$_{coolingcoilcontrol}$=$\dot{M}_{w,coolingcoil}$/$\dot{M}_{w,coolingcoil,n}$

Condensate flow rate:

$$\dot{M}_{w,condensated} = \dot{M}_{a,coolingcoil} \cdot (\omega_{coolingcoil,su} - \omega_{coolingcoil,ex}) \tag{856}$$

$$M_{w,condensated} = \int_{\tau_1}^{\tau_2} \dot{M}_{w,condensated} \, \mathrm{d}\tau \tag{857}$$

Pressure drop:

$$\Delta p_{coolingcoil} = \Delta p_{coolingcoil,n} \cdot \dot{M}_{a,coolingcoil} / \dot{M}_{a,coolingcoil,n} \tag{858}$$

3.6 Post-heating coil

Selection and sizing:

Sizing data:

Output:

$\dot{Q}_{postheatingcoil,n}$, $\dot{M}_{w,postheatingcoil,n}$, AU$_{postheatingcoil,n}$

Inputs:

$$t_{w,postheatingcoil,su,n} = 70 \ [^\circ\mathrm{C}] \tag{859}$$

$$t_{w,postheatingcoil,ex,n} = 50 \ [^\circ\mathrm{C}] \tag{860}$$

$$t_{a,postheatingcoil,su,n} = 12 \ [^\circ\mathrm{C}] \tag{861}$$

$\dot{M}_{a,mainfan,n}$

$$t_{a,postheatingcoil,ex,n} = 20 \ [\mathrm{C}] \tag{862}$$

Calculation:

$$\dot{M}_{a,postheatingcoil,n} = \dot{M}_{a,mainfan,n} \tag{863}$$

$$\dot{Q}_{postheatingcoil,n} = \dot{M}_{a,postheatingcoil,n} \cdot (c_{p,a} + \omega_{ref} \cdot c_{p,g}) \cdot (t_{a,postheatingcoil,ex,n} - t_{a,postheatingcoil,su,n}) \tag{864}$$

$$\dot{M}_{w,postheatingcoil,n} = \frac{\dot{Q}_{postheatingcoil,n}}{c_f \cdot (t_{w,postheatingcoil,su,n} - t_{w,postheatingcoil,ex,n})} \tag{865}$$

$$\epsilon_{postheatingcoil,n} = \frac{t_{a,postheatingcoil,ex,n} - t_{a,postheatingcoil,su,n}}{t_{w,postheatingcoil,su,n} - t_{a,postheatingcoil,su,n}} \quad (866)$$

$\epsilon_{postheatingcoil,n}$=(1-exp(-NTU$_{postheatingcoil,n}$))
NTU$_{postheatingcoil,n}$=AU$_{postheatingcoil,n}$/($\dot{M}_{a,postheatingcoil,n}$*(c$_{p,a}$+$\omega_{ref}$*c$_{p,g}$))

$$\Delta p_{postheatingcoil,n} = 80 \text{ [Pa]} \quad (867)$$

Simulation model

Outputs:

X$_{postheatingcoilcontrol}$, t$_{a,postheatingcoil,ex}$, $\omega_{postheatingcoil,ex}$, X$_{CO2,postheatingcoil,ex}$, air side pressure drop, $\dot{Q}_{postheatingcoil}$, $\dot{M}_{w,postheatingcoil}$, t$_{w,postheatingcoil,ex}$, water side pressure drop

Inputs:

$\dot{M}_{a,coolingcoil}$

t$_{a,coolingcoil,ex}$

$\omega_{coolingcoil,ex}$

X$_{CO2,coolingcoil,ex}$

t$_{hotopenheader,sec,ex}$

see § 1. 6.1;2

Control input:

t$_{a,postheatingcoil,ex,set}$: see § 10

f$_{postheatingcoil}$: see § 10

Parameters:

AU$_{postheatingcoil,n}$

Simulation model:

$$t_{w,postheatingcoil,su} = t_{hotopenheader,sec,ex} + \frac{\dot{W}_{postheatingcoilpump}}{c_f \cdot \dot{M}_{w,postheatingcircuit}} \quad (868)$$

(if neglecting piping heat loss)

$$\dot{M}_{a,postheatingcoil} = \dot{M}_{a,mainfan} \quad (869)$$

$$t_{a,postheatingcoil,su} = t_{a,coolingcoil,ex} \quad (870)$$

$$\omega_{postheatingcoil,su} = \omega_{coolingcoil,ex} \quad (871)$$

$$X_{CO2,postheatingcoil,su} = X_{CO2,coolingcoil,ex} \quad (872)$$

$$\omega_{postheatingcoil,ex} = \omega_{postheatingcoil,su} \quad (873)$$

$$X_{CO2,postheatingcoil,ex} = X_{CO2,postheatingcoil,su} \quad (874)$$

if perfect control, then,

$$t_{a,postheatingcoil,ex,ON} = \max\left(t_{a,postheatingcoil,su},\ t_{a,postheatingcoil,ex,set}\right) \quad (875)$$

$$t_{a,postheatingcoil,ex} = \text{If}(f_{postheatingcoil},\ 1,\ t_{a,postheatingcoil,su},\ t_{a,postheatingcoil,ex,ON},\ t_{a,postheatingcoil,ex,ON}) \quad (876)$$

$$\dot{Q}_{postheatingcoil} = \dot{M}_{a,postheatingcoil} \cdot (c_{p,a} + \omega_{ref} \cdot c_{p,g}) \cdot (t_{a,postheatingcoil,ex} - t_{a,postheatingcoil,su}) \quad (877)$$

Determination of the cooling water flow rate:

$$\dot{Q}_{postheatingcoil} = \epsilon_{postheatingcoil} \cdot \dot{M}_{w,postheatingcoil} \cdot c_f \cdot (t_{w,postheatingcoil,su} - t_{a,postheatingcoil,su}) \quad (878)$$

Determination of postheating coil exhaust water temperature

$$t_{w,postheating,ex} = t_{hotopenheader,sec,ex} - \left(\frac{\dot{Q}_{postheatingcoil}}{c_f \cdot \dot{M}_{w,postheatingcircuit}} \right) \quad (879)$$

Simplified law of variation of the water side effectiveness:

$$\epsilon_{postheatingcoil} = (\epsilon_{postheatingcoil,n} - 1) \cdot \dot{M}_{w,postheatingcoil} / \dot{M}_{w,postheatingcoil,n} + 1 \quad (880)$$

$\epsilon_{postheatingcoil}$=$\epsilon_{postheatingcoil,n}$

Water flow rate ratio:

$$X_{postheatingcoil} = \dot{M}_{w,postheatingcoil} / \dot{M}_{w,postheatingcoil,n} \quad (881)$$

$$Q_{postheatingcoil} = \int_{\tau_1}^{\tau_2} \dot{Q}_{postheatingcoil} \, \mathrm{d}\tau \quad (882)$$

$$Q_{postheatingcoil,kWh} = Q_{postheatingcoil} / J/kWh \quad (883)$$

$$\Delta p_{postheatingcoil} = \Delta p_{postheatingcoil,n} \cdot \dot{M}_{a,postheatingcoil} / \dot{M}_{a,postheatingcoil,n} \quad (884)$$

3.7 Main fan:

Sizing:

Outputs:

$\dot{M}_{a,mainfan,n}$, $\epsilon_{s,mainfan,n}$

Inputs:

$\dot{M}_{a,supplyduct,n}$: see §4

$\Delta p_{fresh,recovery,n}$, $\Delta p_{fresh,econo,n}$, $\Delta p_{filter,n}$, $\Delta p_{preheatingcoil,n}$,$\Delta p_{coolingcoil,n}$, $\Delta p_{postheatingcoil,n}$, $\Delta p_{supplyduct,n}$, $\Delta p_{TU,n}$

Calculation:

$$\dot{M}_{a,mainfan,n} = \dot{M}_{a,supplyduct,su,n} \quad (885)$$

$$\Delta p_{mainfan,n} = \Delta p_{fresh,recovery,n} + \Delta p_{fresh,econo,n} + \Delta p_{filter,n} + \Delta p_{preheatingcoil,n} + \Delta p_{adiabhum,n} + \Delta p_{coolingcoil,n} + \Delta p_{postheatingcoil}$$

$$\epsilon_{s,mainfan,n} = 0.6 \ [-] \quad (887)$$

(motor included)

Simulation:

Outputs:

$\dot{M}_{a,mainfan}$,$\Delta p_{mainfan}$, $\dot{W}_{mainfan}$, $t_{a,mainfan,ex}$, $\omega_{mainfan,ex}$, $X_{CO2,mainfan,ex}$

Inputs:

$\dot{M}_{a,supplyduct,su}$

$t_{a,postheatincoil,ex}$

$\omega_{postheatingcoil,ex}$

$X_{CO2,postheatingcoil,ex}$

$\Delta p_{fresh,recovery}$

$\Delta p_{fresh,econo}$

Δp_{filter}

$\Delta p_{preheatingcoil}$

$\Delta p_{coolingcoil}$

$\Delta p_{postheatingcoil}$

$\Delta p_{supplyduct}$: see § 4

Δp_{TU}: see § 5

Parameter:

$\epsilon_{s,mainfan,n}$

(coming from sizing)

Simulation model:

$$\dot{M}_{a,mainfan} = \dot{M}_{a,supplyduct,su} \tag{888}$$

$$t_{a,mainfan,su} = t_{a,postheatingcoil,ex} \tag{889}$$

$$\omega_{mainfan,su} = \omega_{postheatingcoil,ex} \tag{890}$$

$$X_{CO2,mainfan,su} = X_{CO2,postheatingcoil,ex} \tag{891}$$

$$\Delta p_{mainfan} = \Delta p_{fresh,recovery} + \Delta p_{fresh,econo} + \Delta p_{filter} + \Delta p_{preheatingcoil} + \Delta p_{adiabhum} + \Delta p_{coolingcoil} + \Delta p_{postheatingcoil} + \Delta p_{supplydu}$$

$$\epsilon_{s,mainfan} = \epsilon_{s,mainfan,n} \tag{893}$$

(might be also identified from fan characteristics)

$$\dot{W}_{mainfan} = f_{mainfan} \cdot \dot{V}_{a,mainfan} \cdot \frac{\Delta p_{mainfan}}{\epsilon_{s,mainfan}} \tag{894}$$

$$\dot{V}_{a,mainfan} = \dot{M}_{a,mainfan} \cdot v_a \tag{895}$$

$$W_{mainfan} = \int_{\tau_1}^{\tau_2} \dot{W}_{mainfan} \, \mathrm{d}\tau \tag{896}$$

$$W_{mainfan,kWh} = W_{mainfan}/J/kWh \tag{897}$$

$$t_{a,mainfan,ex} = t_{a,mainfan,su} + \frac{\dot{W}_{mainfan}}{\dot{M}_{a,mainfan} \cdot c_{p,ref} + Watt/Kelvin_{min}} \tag{898}$$

(in fair approximation and if the motor is inside the fan box)

$$\omega_{mainfan,ex} = \omega_{mainfan,su} \tag{899}$$

$$X_{CO2,mainfan,ex} = X_{CO2,mainfan,su} \tag{900}$$

3.8 Steam humidifier:

Outputs:

$T_{a,steamhumidifier,ex}$

$\omega_{steamhumidifier,ex}$

$\dot{M}_{steamhumidifier}$

$\dot{M}_{w,electricalhumidifier}$

$\dot{W}_{electricalhumidifier}$

Inputs:

$\dot{M}_{a,mainfan}$

$t_{a,mainfan,ex}$

$\omega_{mainfan,ex}$

$X_{CO2,mainfan,ex}$

$\mathbf{h}_{w,steamboiler,ex}$

(if centralized production by steam gas boiler: see § 7.3)

t_{steam}=101 [C]

p_{steam}=1E5 [Pa]

(if decentralized production by steam electrical boiler: see § 7.3)

$$t_{w,electricalhumidifier,su} = 15 \ [C] \tag{901}$$

Control input:

$\mathbf{f}_{electricalhumidification}$**: see § 10**

$\mathbf{f}_{centralizedsteamproduction}$**: see § 10**

$\omega_{steamhumidifier,ex,set}$**: see § 10**

Parameters:

$$\eta_{electricalhumidifier} = 0.9 \ [-] \tag{902}$$

$$purgefraction_{electrichum} = 0.1 \ [-] \tag{903}$$

Simulation model:

$$\dot{M}_{a,steamhumidifier} = \dot{M}_{a,mainfan} \tag{904}$$

$$t_{a,steamhumidifier,su} = t_{a,mainfan,ex} \tag{905}$$

$$\omega_{steamhumidifier,su} = \omega_{mainfan,ex} \quad (906)$$

$$X_{CO2,steamhumidifier,su} = X_{CO2,mainfan,ex} \quad (907)$$

$$h_{a,steamhumidifier,su} = c_{p,a} \cdot t_{a,steamhumidifier,su} + \omega_{steamhumidifier,su} \cdot (c_{p,g} \cdot t_{a,steamhumidifier,su} + h_{fg,0}) \quad (908)$$

$$X_{CO2,steamhumidifier,ex} = X_{CO2,steamhumidifier,su} \quad (909)$$

and, if perfect control:

$$\omega_{steamhumidifier,ex,ON} = \omega_{steamhumidifier,ex,set} \quad (910)$$

$$f_{steamhumidification} = f_{electricalhumidification} + f_{centralizedsteamproduction} \quad (911)$$

$$\omega_{steamhumidifier,ex} = if\left(f_{steamhumidification},\ 1,\ \omega_{steamhumidifier,su},\ \omega_{steamhumidifier,ex,ON},\ \omega_{steamhumidifier,ex,ON}\right) \quad (912)$$

h_{steam}=$h_{fg,0}$+$c_{p,g}$*t_{steam}

or

$$h_{steam} = \mathrm{h}\left(Steam,\ \mathrm{P} = 1 \times 10^5,\ \mathrm{x} = 1\right) \quad (913)$$

(if saturated steam at 1 bar)

$$h_{a,steamhumidifier,ex} = h_{a,steamhumidifier,su} + (\omega_{steamhumidifier,ex} - \omega_{steamhumidifier,su}) \cdot h_{steam} \quad (914)$$

$$h_{a,steamhumidifier,ex} = c_{p,a} \cdot T_{a,steamhumidifier,ex} + \omega_{steamhumidifier,ex} \cdot (c_{p,g} \cdot T_{a,steamhumidifier,ex} + h_{fg,0}) \quad (915)$$

$$\dot{M}_{steam} = \max\left(0,\ \dot{M}_{a,steamhumidifier} \cdot (\omega_{steamhumidifier,ex} - \omega_{steamhumidifier,su})\right) \quad (916)$$

If electrical humidifier, then,

$\dot{M}_{w,steamgenerator}$=$\dot{M}_{w,steamhum}$/(1-steampurgefraction)
$M_{w,steamgenerator}$= integral($\dot{M}_{w,steamgenerator}$,$\tau$,$\tau_1$,$\tau_2$, $\Delta\tau$)
$\dot{W}_{electricalhumidifier}$=$\dot{M}_{w,steamgenerator}$*($h_{steam,steamhum,su}$-$c_f$*$t_{w,steamgenerator,su}$)/$\eta_{electricalhumidifier}$
$W_{electricalhumidifier}$= integral($\dot{W}_{electricalhumidifier}$,$\tau$,$\tau_1$,$\tau_2$, $\Delta\tau$)
$W_{electricalhumidifier,kWh}$=$W_{electricalhumidifier}$/J \kWh

(if decentralized production by steam electrical boiler)

3.9 Electricity, heating and cooling demands of the air handling unit without electrical steam humidifier:

$$\dot{W}_{AHU} = \dot{W}_{returnfan} + \dot{W}_{mainfan} + \dot{W}_{preheating} \quad (917)$$

$$W_{AHU,kWh} = W_{returnfan,kWh} + W_{mainfan,kWh} + W_{preheating,kWh} \quad (918)$$

$$\dot{Q}_{heating,AHU} = \dot{Q}_{preheatingcoil} + \dot{Q}_{postheatingcoil} \quad (919)$$

$$Q_{heating,AHU,kWh} = Q_{preheatingcoil,kWh} + Q_{postheatingcoil,kWh} \quad (920)$$

$$\dot{Q}_{cooling,AHU} = \dot{Q}_{coolingcoil} \quad (921)$$

$$Q_{cooling,AHU,kWh} = Q_{coolingcoil,kWh} \quad (922)$$

$BOOKMARK 04. SUPPLY DUCT

4. SUPPLY DUCT:

Selection and sizing (still to be done):

Outputs:

$D_{supplyduct}$,$A_{leakage,supplyduct}$,$U_{supplyduct}$

Inputs:

$L_{supplyduct}$

$\dot{M}_{a,returnduct,ex,n}$

Calculation:

$$\dot{M}_{a,supplyduct,su,n} = \dot{M}_{a,returnduct,ex,n} \tag{923}$$

$$\Delta p_{supplyduct,n} = 160 \ [\text{Pa}] \tag{924}$$

Simulation:

Outputs:

$\dot{M}_{a,supplyduct,ex}$, $\dot{M}_{a,leakage,supplyduct}$, $\Delta p_{supplyduct}$, $t_{a,supplyduct,ex}$, $\omega_{supplyduct,ex}$, $X_{CO2,supplyduct,ex}$

Inputs:

$\dot{M}_{a,steamhum}$

$T_{a,steamhum,ex}$

$\omega_{steamhum,ex}$

$t_{env,supplyduct}$

(in order to calculate the heat exchange)

$p_{supplyduct}$

(in order to calculate the leakage)

Parameters:

(coming from supply duct sizing)

$D_{supplyduct}$,$L_{supplyduct}$,$A_{leakage,supplyduct}$,$U_{supplyduct}$

Simulation model:

$$\dot{M}_{a,supplyduct,ex,floor} = \dot{M}_{a,supplyduct,ex,01}+\dot{M}_{a,supplyduct,ex,02}+\dot{M}_{a,supplyduct,ex,03}+\dot{M}_{a,supplyduct,ex,04}+\dot{M}_{a,supplyduct,ex,05} \tag{925}$$

$$\dot{M}_{a,supplyduct,ex} = n_{floor} \cdot \dot{M}_{a,supplyduct,ex,floor} \tag{926}$$

$$\dot{M}_{a,supplyduct,su} = \dot{M}_{a,supplyduct,ex} + \dot{M}_{a,supplyduct,exfiltr} \tag{927}$$

$$\dot{M}_{a,supplyduct,exfiltr} = 0 \tag{928}$$

if the exfiltration is neglected

$$t_{a,supplyduct,su} = T_{a,steamhumidifier,ex} \tag{929}$$

$$\omega_{supplyduct,su} = \omega_{steamhumidifier,ex} \tag{930}$$

$$X_{CO2,supplyduct,su} = X_{CO2,steamhumidifier,ex} \tag{931}$$

$$\Delta p_{supplyduct} = \Delta p_{supplyduct,n} \cdot \left(\dot{M}_{a,supplyduct,su}/\dot{M}_{a,supplyduct,su,n}\right)^2 \tag{932}$$

$$t_{a,supplyduct,ex} = t_{a,supplyduct,su} \tag{933}$$

(if heat exchange is neglected)

$$\omega_{supplyduct,ex} = \omega_{supplyduct,su} \tag{934}$$

(if condensation along the duct is neglected)

$$X_{CO2,supplyduct,ex} = X_{CO2,supplyduct,su} \tag{935}$$

$BOOKMARK 05. TERMINAL UNITS

5. TERMINAL UNITS:

Option: fan coils

$$\Delta p_{TU,n} = 0 \ [\text{Pa}] \tag{936}$$

$$\Delta p_{TU} = 0 \ [\text{Pa}] \tag{937}$$

(no supplement of pressure drop in the air distribution network)

5.1 Heating:

Sizing and commissioning:

Outputs:

$\dot{Q}_{s,heatingTU,n}$, $\dot{W}_{TUheatingfan,n}$, $\text{AU}_{TUheatingcoil}$, $\Delta p_{w,TUheatingcoil}$

Inputs:

$\text{AU}_{envelope}$

$$t_{w,TUheating,su,n} = 70 \ [\text{C}] \tag{938}$$

$$t_{w,TUheating,ex,n} = 50 \ [\text{C}] \tag{939}$$

$$t_{a,in,heating,n} = 20 \ [\text{C}] \tag{940}$$

$$t_{a,TUheating,ex,n} = 35 \ [\text{C}] \tag{941}$$

Equations:

$\dot{Q}_{envelope,n}$=$\text{AU}_{envelope}$*($t_{out,n}$-$t_{a,in,heating,n}$)

$\dot{Q}_{s,heatingTU,n}$=-$\dot{Q}_{envelope,n}$

(if ventilation losses were already compensated by the AHU)

$$\dot{Q}_{s,heatingTU,01,n} = 11.8 \times 10^3 \ [\text{W}] \tag{942}$$

$$\dot{Q}_{s,heatingTU,02,n} = 8.4 \times 10^3 \text{ [W]} \tag{943}$$

$$\dot{Q}_{s,heatingTU,03,n} = 11.8 \times 10^3 \text{ [W]} \tag{944}$$

$$\dot{Q}_{s,heatingTU,04,n} = 8.4 \times 10^3 \text{ [W]} \tag{945}$$

$$\dot{Q}_{s,heatingTU,05,n} = 8.4 \times 10^3 \text{ [W]} \tag{946}$$

(values extracted from simulation on reference year)

$$\dot{Q}_{s,heatingTU,01,n} = \dot{Q}_{TUheatingcoil,01,n} + \dot{W}_{TUfan,01,n} \tag{947}$$

$$\dot{Q}_{s,heatingTU,02,n} = \dot{Q}_{TUheatingcoil,02,n} + \dot{W}_{TUfan,02,n} \tag{948}$$

$$\dot{Q}_{s,heatingTU,03,n} = \dot{Q}_{TUheatingcoil,03,n} + \dot{W}_{TUfan,03,n} \tag{949}$$

$$\dot{Q}_{s,heatingTU,04,n} = \dot{Q}_{TUheatingcoil,04,n} + \dot{W}_{TUfan,04,n} \tag{950}$$

$$\dot{Q}_{s,heatingTU,05,n} = \dot{Q}_{TUheatingcoil,05,n} + \dot{W}_{TUfan,05,n} \tag{951}$$

Water pressure drop in nominal conditions:

$$\Delta p_{w,TUheatingcoil,n} = 0.2 \times 10^5 \text{ [Pa]} \tag{952}$$

Water flow rates:

$$\dot{M}_{w,TUheatingcoil,01,n} = \frac{\dot{Q}_{TUheatingcoil,01,n}}{c_f \cdot (t_{w,TUheating,su,n} - t_{w,TUheating,ex,n})} \tag{953}$$

$$\dot{M}_{w,TUheatingcoil,02,n} = \frac{\dot{Q}_{TUheatingcoil,02,n}}{c_f \cdot (t_{w,TUheating,su,n} - t_{w,TUheating,ex,n})} \tag{954}$$

$$\dot{M}_{w,TUheatingcoil,03,n} = \frac{\dot{Q}_{TUheatingcoil,03,n}}{c_f \cdot (t_{w,TUheating,su,n} - t_{w,TUheating,ex,n})} \tag{955}$$

$$\dot{M}_{w,TUheatingcoil,04,n} = \frac{\dot{Q}_{TUheatingcoil,04,n}}{c_f \cdot (t_{w,TUheating,su,n} - t_{w,TUheating,ex,n})} \tag{956}$$

$$\dot{M}_{w,TUheatingcoil,05,n} = \frac{\dot{Q}_{TUheatingcoil,05,n}}{c_f \cdot (t_{w,TUheating,su,n} - t_{w,TUheating,ex,n})} \tag{957}$$

Air temperature at coil supply:

$$t_{a,TUheatingcoil,su,01,n} = t_{a,in,heating,n} + \frac{\dot{W}_{TUfan,01,n}}{\dot{M}_{a,TUheating,01,n} \cdot c_{p,ref}} \tag{958}$$

$$t_{a,TUheatingcoil,su,02,n} = t_{a,in,heating,n} + \frac{\dot{W}_{TUfan,02,n}}{\dot{M}_{a,TUheating,02,n} \cdot c_{p,ref}} \tag{959}$$

$$t_{a,TUheatingcoil,su,03,n} = t_{a,in,heating,n} + \frac{\dot{W}_{TUfan,03,n}}{\dot{M}_{a,TUheating,03,n} \cdot c_{p,ref}} \tag{960}$$

$$t_{a,TUheatingcoil,su,04,n} = t_{a,in,heating,n} + \frac{\dot{W}_{TUfan,04,n}}{\dot{M}_{a,TUheating,04,n} \cdot c_{p,ref}} \tag{961}$$

$$t_{a,TUheatingcoil,su,05,n} = t_{a,in,heating,n} + \frac{\dot{W}_{TUfan,05,n}}{\dot{M}_{a,TUheating,05,n} \cdot c_{p,ref}} \tag{962}$$

Air flow rates:

$$\dot{M}_{a,TUheating,01,n} = \frac{\dot{Q}_{s,heatingTU,01,n}}{c_{p,ref} \cdot (t_{a,TUheating,ex,n} - t_{a,in,heating,n})} \tag{963}$$

$$\dot{M}_{a,TUheating,02,n} = \frac{\dot{Q}_{s,heatingTU,02,n}}{c_{p,ref} \cdot (t_{a,TUheating,ex,n} - t_{a,in,heating,n})} \tag{964}$$

$$\dot{M}_{a,TUheating,03,n} = \frac{\dot{Q}_{s,heatingTU,03,n}}{c_{p,ref} \cdot (t_{a,TUheating,ex,n} - t_{a,in,heating,n})} \tag{965}$$

$$\dot{M}_{a,TUheating,04,n} = \frac{\dot{Q}_{s,heatingTU,04,n}}{c_{p,ref} \cdot (t_{a,TUheating,ex,n} - t_{a,in,heating,n})} \tag{966}$$

$$\dot{M}_{a,TUheating,05,n} = \frac{\dot{Q}_{s,heatingTU,05,n}}{c_{p,ref} \cdot (t_{a,TUheating,ex,n} - t_{a,in,heating,n})} \tag{967}$$

Simulation model:

Outputs:

$\dot{Q}_{TUheatingcoil}$, $t_{w,TUheating,ex}$, $\dot{W}_{TUfan...}$

Inputs:

$$t_{w,TUheating,su} = 50 \ [°C] \tag{968}$$

(could also vary according some control strategy!)

Control inputs:

f_{TUfan}: see § 10

$f_{w,heatingTU}$: see § 10

gain of proportional control:

$C_{heatingTU}$=0.5 [K-1]: see §10

set point:

$t_{a,in,heating,set}$: see § 10

Parameters:

$AU_{TUheatingcoil,n}$ and corresponding temperatures and flow rate(s)...

Air mixing effectiveness:

$$\epsilon_{mixing,heatingTU,01} = 1 \ [-] \tag{969}$$

$$\epsilon_{mixing,heatingTU,02} = 1 \ [-] \tag{970}$$

$$\epsilon_{mixing,heatingTU,03} = 1 \ [-] \tag{971}$$

$$\epsilon_{mixing,heatingTU,04} = 1 \ [-] \tag{972}$$

$$\epsilon_{mixing,heatingTU,05} = 1 \tag{973}$$

(related to the type of each terminal unit and to its position)

(might be even bigger than 1 thanks to stratification, if the unit is near the floor)

Air temperature at terminal unit supply:

$$t_{a,TUheating,su,01} = t_{a,in,01} + (1 - \epsilon_{mixing,heatingTU,01}) \cdot (t_{w,TUheating,su} - t_{a,in,01}) \tag{974}$$

$$t_{a,TUheating,su,02} = t_{a,in,02} + (1 - \epsilon_{mixing,heatingTU,02}) \cdot (t_{w,TUheating,su} - t_{a,in,02}) \tag{975}$$

$$t_{a,TUheating,su,03} = t_{a,in,03} + (1 - \epsilon_{mixing,heatingTU,03}) \cdot (t_{w,TUheating,su} - t_{a,in,03}) \tag{976}$$

$$t_{a,TUheating,su,04} = t_{a,in,04} + (1 - \epsilon_{mixing,heatingTU,04}) \cdot (t_{w,TUheating,su} - t_{a,in,04}) \tag{977}$$

$$t_{a,TUheating,su,05} = t_{a,in,05} + (1 - \epsilon_{mixing,heatingTU,05}) \cdot (t_{w,TUheating,su} - t_{a,in,05}) \tag{978}$$

Air flow rate:

$$\dot{M}_{a,TUheating,01} = \dot{M}_{a,TUheating,01,n} \tag{979}$$

$$\dot{M}_{a,TUheating,02} = \dot{M}_{a,TUheating,02,n} \tag{980}$$

$$\dot{M}_{a,TUheating,03} = \dot{M}_{a,TUheating,03,n} \tag{981}$$

$$\dot{M}_{a,TUheating,04} = \dot{M}_{a,TUheating,04,n} \tag{982}$$

$$\dot{M}_{a,TUheating,05} = \dot{M}_{a,TUheating,05,n} \tag{983}$$

Fan consumption:

$$\dot{W}_{TUfan,01} = f_{TUfan} \cdot \dot{W}_{TUfan,01,n} \tag{984}$$

$$\dot{W}_{TUfan,02} = f_{TUfan} \cdot \dot{W}_{TUfan,02,n} \tag{985}$$

$$\dot{W}_{TUfan,03} = f_{TUfan} \cdot \dot{W}_{TUfan,03,n} \tag{986}$$

$$\dot{W}_{TUfan,04} = f_{TUfan} \cdot \dot{W}_{TUfan,04,n} \tag{987}$$

$$\dot{W}_{TUfan,05} = f_{TUfan} \cdot \dot{W}_{TUfan,05,n} \tag{988}$$

$$W_{TUfan,01} = \int_{\tau_1}^{\tau_2} \dot{W}_{TUfan,01} \, \mathbf{d}\tau \tag{989}$$

$$W_{TUfan,02} = \int_{\tau_1}^{\tau_2} \dot{W}_{TUfan,02} \, \mathbf{d}\tau \tag{990}$$

$$W_{TUfan,03} = \int_{\tau_1}^{\tau_2} \dot{W}_{TUfan,03} \, \mathbf{d}\tau \tag{991}$$

$$W_{TUfan,04} = \int_{\tau_1}^{\tau_2} \dot{W}_{TUfan,04} \, \mathbf{d}\tau \tag{992}$$

$$W_{TUfan,05} = \int_{\tau_1}^{\tau_2} \dot{W}_{TUfan,05} \, \mathbf{d}\tau \tag{993}$$

$$W_{TUfan,01,kWh} = W_{TUfan,01}/J/kWh \tag{994}$$

$$W_{TUfan,02,kWh} = W_{TUfan,02}/J/kWh \tag{995}$$

$$W_{TUfan,03,kWh} = W_{TUfan,03}/J/kWh \tag{996}$$

$$W_{TUfan,04,kWh} = W_{TUfan,04}/J/kWh \tag{997}$$

$$W_{TUfan,05,kWh} = W_{TUfan,05}/J/kWh \tag{998}$$

$$\dot{W}_{TUfans,floor} = \dot{W}_{TUfan,01} + \dot{W}_{TUfan,02} + \dot{W}_{TUfan,03} + \dot{W}_{TUfan,04} + \dot{W}_{TUfan,05} \tag{999}$$

$$\dot{W}_{TUfans} = n_{floor} \cdot \dot{W}_{TUfans,floor} \tag{1000}$$

$$W_{TUfans,floor,kWh} = W_{TUfan,01,kWh} + W_{TUfan,02,kWh} + W_{TUfan,03,kWh} + W_{TUfan,04,kWh} + W_{TUfan,05,kWh} \tag{1001}$$

$$W_{TUfans,kWh} = n_{floor} \cdot W_{TUfans,floor,kWh} \tag{1002}$$

Air temperature at coil supply:

$$t_{a,TUheatingcoil,su,01} = t_{a,TUheating,su,01} + \frac{\dot{W}_{TUfan,01}}{\dot{M}_{a,TUheating,01} \cdot c_{p,ref}} \tag{1003}$$

$$t_{a,TUheatingcoil,su,02} = t_{a,TUheating,su,02} + \frac{\dot{W}_{TUfan,02}}{\dot{M}_{a,TUheating,02} \cdot c_{p,ref}} \tag{1004}$$

$$t_{a,TUheatingcoil,su,03} = t_{a,TUheating,su,03} + \frac{\dot{W}_{TUfan,03}}{\dot{M}_{a,TUheating,03} \cdot c_{p,ref}} \tag{1005}$$

$$t_{a,TUheatingcoil,su,04} = t_{a,TUheating,su,04} + \frac{\dot{W}_{TUfan,04}}{\dot{M}_{a,TUheating,04} \cdot c_{p,ref}} \tag{1006}$$

$$t_{a,TUheatingcoil,su,05} = t_{a,TUheating,su,05} + \frac{\dot{W}_{TUfan,05}}{\dot{M}_{a,TUheating,05} \cdot c_{p,ref}} \tag{1007}$$

Maximal heat output (with control valve fully open):

$$\dot{Q}_{TUheatingcoil,01,max} = \dot{Q}_{TUheatingcoil,01,n} \cdot \frac{t_{w,TUheating,su} - t_{a,TUheatingcoil,su,01}}{t_{w,TUheating,su,n} - t_{a,TUheatingcoil,su,01,n}} \tag{1008}$$

$$\dot{Q}_{TUheatingcoil,02,max} = \dot{Q}_{TUheatingcoil,02,n} \cdot \frac{t_{w,TUheating,su} - t_{a,TUheatingcoil,su,02}}{t_{w,TUheating,su,n} - t_{a,TUheatingcoil,su,02,n}} \tag{1009}$$

$$\dot{Q}_{TUheatingcoil,03,max} = \dot{Q}_{TUheatingcoil,03,n} \cdot \frac{t_{w,TUheating,su} - t_{a,TUheatingcoil,su,03}}{t_{w,TUheating,su,n} - t_{a,TUheatingcoil,su,03,n}} \tag{1010}$$

$$\dot{Q}_{TUheatingcoil,04,max} = \dot{Q}_{TUheatingcoil,04,n} \cdot \frac{t_{w,TUheating,su} - t_{a,TUheatingcoil,su,04}}{t_{w,TUheating,su,n} - t_{a,TUheatingcoil,su,04,n}} \tag{1011}$$

$$\dot{Q}_{TUheatingcoil,05,max} = \dot{Q}_{TUheatingcoil,05,n} \cdot \frac{t_{w,TUheating,su} - t_{a,TUheatingcoil,su,05}}{t_{w,TUheating,su,n} - t_{a,TUheatingcoil,su,05,n}} \tag{1012}$$

Ideal proportional feed back control and coil heat output:

$$X_{heatingTU,01} = \min\left(1,\ \max\left(0,\ C_{heatingTU} \cdot (t_{a,in,heating,01,set} - t_{a,in,01})\right)\right) \tag{1013}$$

$$\dot{Q}_{TUheatingcoil,01} = f_{w,heatingTU} \cdot X_{heatingTU,01} \cdot \dot{Q}_{TUheatingcoil,01,max} \tag{1014}$$

$$X_{heatingTU,02} = \min\left(1,\ \max\left(0,\ C_{heatingTU} \cdot (t_{a,in,heating,02,set} - t_{a,in,02})\right)\right) \tag{1015}$$

$$\dot{Q}_{TUheatingcoil,02} = f_{w,heatingTU} \cdot X_{heatingTU,02} \cdot \dot{Q}_{TUheatingcoil,02,max} \tag{1016}$$

$$X_{heatingTU,03} = \min\left(1,\ \max\left(0,\ C_{heatingTU} \cdot \left(t_{a,in,heating,03,set} - t_{a,in,03}\right)\right)\right) \tag{1017}$$

$$\dot{Q}_{TUheatingcoil,03} = f_{w,heatingTU} \cdot X_{heatingTU,03} \cdot \dot{Q}_{TUheatingcoil,03,max} \tag{1018}$$

$$X_{heatingTU,04} = \min\left(1,\ \max\left(0,\ C_{heatingTU} \cdot \left(t_{a,in,heating,04,set} - t_{a,in,04}\right)\right)\right) \tag{1019}$$

$$\dot{Q}_{TUheatingcoil,04} = f_{w,heatingTU} \cdot X_{heatingTU,04} \cdot \dot{Q}_{TUheatingcoil,04,max} \tag{1020}$$

$$X_{heatingTU,05} = \min\left(1,\ \max\left(0,\ C_{heatingTU} \cdot \left(t_{a,in,heating,05,set} - t_{a,in,05}\right)\right)\right) \tag{1021}$$

$$\dot{Q}_{TUheatingcoil,05} = f_{w,heatingTU} \cdot X_{heatingTU,05} \cdot \dot{Q}_{TUheatingcoil,05,max} \tag{1022}$$

$$Q_{TUheatingcoil,01} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUheatingcoil,01}\, \mathbf{d}\tau \tag{1023}$$

$$Q_{TUheatingcoil,01,kWh} = Q_{TUheatingcoil,01}/J/kWh \tag{1024}$$

$$Q_{TUheatingcoil,02} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUheatingcoil,02}\, \mathbf{d}\tau \tag{1025}$$

$$Q_{TUheatingcoil,02,kWh} = Q_{TUheatingcoil,02}/J/kWh \tag{1026}$$

$$Q_{TUheatingcoil,03} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUheatingcoil,03}\, \mathbf{d}\tau \tag{1027}$$

$$Q_{TUheatingcoil,03,kWh} = Q_{TUheatingcoil,03}/J/kWh \tag{1028}$$

$$Q_{TUheatingcoil,04} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUheatingcoil,04}\, \mathbf{d}\tau \tag{1029}$$

$$Q_{TUheatingcoil,04,kWh} = Q_{TUheatingcoil,04}/J/kWh \tag{1030}$$

$$Q_{TUheatingcoil,05} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUheatingcoil,05}\, \mathbf{d}\tau \tag{1031}$$

$$Q_{TUheatingcoil,05,kWh} = Q_{TUheatingcoil,05}/J/kWh \tag{1032}$$

$$\dot{Q}_{TUheatingcoils,floor} = \dot{Q}_{TUheatingcoil,01} + \dot{Q}_{TUheatingcoil,02} + \dot{Q}_{TUheatingcoil,03} + \dot{Q}_{TUheatingcoil,04} + \dot{Q}_{TUheatingcoil,05} \tag{1033}$$

$$\dot{Q}_{TUheatingcoils} = n_{floor} \cdot \dot{Q}_{TUheatingcoils,floor} \tag{1034}$$

$$Q_{TUheatingcoils,floor,kWh} = Q_{TUheatingcoil,01,kWh} + Q_{TUheatingcoil,02,kWh} + Q_{TUheatingcoil,03,kWh} + Q_{TUheatingcoil,04,kWh} + Q_{TUheati}$$

$$Q_{TUheatingcoils,kWh} = n_{floor} \cdot Q_{TUheatingcoils,floor,kWh} \tag{1036}$$

Total heat output of the terminal unit:

$$\dot{Q}_{s,heatingTU,01} = \dot{Q}_{TUheatingcoil,01} + \dot{W}_{TUfan,01} \tag{1037}$$

$$\dot{Q}_{s,heatingTU,02} = \dot{Q}_{TUheatingcoil,02} + \dot{W}_{TUfan,02} \tag{1038}$$

$$\dot{Q}_{s,heatingTU,03} = \dot{Q}_{TUheatingcoil,03} + \dot{W}_{TUfan,03} \tag{1039}$$

$$\dot{Q}_{s,heatingTU,04} = \dot{Q}_{TUheatingcoil,04} + \dot{W}_{TUfan,04} \tag{1040}$$

$$\dot{Q}_{s,heatingTU,05} = \dot{Q}_{TUheatingcoil,05} + \dot{W}_{TUfan,05} \tag{1041}$$

$$\dot{Q}_{s,heatingTU,floor} = \dot{Q}_{s,heatingTU,01} + \dot{Q}_{s,heatingTU,02} + \dot{Q}_{s,heatingTU,03} + \dot{Q}_{s,heatingTU,04} + \dot{Q}_{s,heatingTU,05} \quad (1042)$$

$$\dot{Q}_{s,heatingTU} = n_{floor} \cdot \dot{Q}_{s,heatingTU,floor} \quad (1043)$$

Average water flow rate (also with digital control):

$$\dot{M}_{w,TUheatingcoil,01} = f_{w,heatingTU} \cdot X_{heatingTU,01} \cdot \dot{M}_{w,TUheatingcoil,01,n} \quad (1044)$$

$$\dot{M}_{w,TUheatingcoil,02} = f_{w,heatingTU} \cdot X_{heatingTU,02} \cdot \dot{M}_{w,TUheatingcoil,02,n} \quad (1045)$$

$$\dot{M}_{w,TUheatingcoil,03} = f_{w,heatingTU} \cdot X_{heatingTU,03} \cdot \dot{M}_{w,TUheatingcoil,03,n} \quad (1046)$$

$$\dot{M}_{w,TUheatingcoil,04} = f_{w,heatingTU} \cdot X_{heatingTU,04} \cdot \dot{M}_{w,TUheatingcoil,04,n} \quad (1047)$$

$$\dot{M}_{w,TUheatingcoil,05} = f_{w,heatingTU} \cdot X_{heatingTU,05} \cdot \dot{M}_{w,TUheatingcoil,05,n} \quad (1048)$$

5.2 Cooling:

Assuming that there is no condensation on in the terminal unit!

Sizing and commissioning:

Outputs:

$\dot{Q}_{s,coolingTU,n}$, $\mathrm{AU}_{TUcoolingcoil}$, $\Delta p_{w,TUcoolingcoil}$

Inputs:

$\mathrm{AU}_{envelope}$

$$t_{w,TUcooling,su,n} = 14 \ [\mathrm{C}] \quad (1049)$$

$$t_{w,TUcooling,ex,n} = 18 \ [\mathrm{C}] \quad (1050)$$

$$t_{a,in,cooling,n} = 24 \ [\mathrm{C}] \quad (1051)$$

$$t_{a,TUcooling,ex,n} = 18 \ [\mathrm{C}] \quad (1052)$$

Equations:

$\dot{Q}_{s,coolingTU,n}$=$\dot{Q}_{s,occ,max}$+$\dot{W}_{light,max}$+$\dot{W}_{appl,max}$+$\dot{Q}_{sun,max}$
$\dot{Q}_{sun,max}$=$\mathrm{A}_{windows}$*$\mathrm{SF}_{windows}$*$\mathrm{I}_{sun,max}$
$\mathrm{I}_{sun,max}$=500 [W/m^2]

(if ventilation heat gains are already compensated by the AHU)

$$\dot{Q}_{s,coolingTU,01,n} = 12 \times 10^3 \ [\mathrm{W}] \quad (1053)$$

$$\dot{Q}_{s,coolingTU,02,n} = 9 \times 10^3 \ [\mathrm{W}] \quad (1054)$$

$$\dot{Q}_{s,coolingTU,03,n} = 12.8 \times 10^3 \ [\mathrm{W}] \quad (1055)$$

$$\dot{Q}_{s,coolingTU,04,n} = 9 \times 10^3 \ [\mathrm{W}] \quad (1056)$$

$$\dot{Q}_{s,coolingTU,05,n} = 9 \times 10^3 \ [\mathrm{W}] \quad (1057)$$

$$\dot{W}_{TUfan,01,n} = 160 \ [\mathrm{W}] \quad (1058)$$

$$\dot{W}_{TUfan,02,n} = 122 \ [\mathrm{W}] \quad (1059)$$

$$\dot{W}_{TUfan,03,n} = 160 \;\; [\mathrm{W}] \tag{1060}$$

$$\dot{W}_{TUfan,04,n} = 122 \;\; [\mathrm{W}] \tag{1061}$$

$$\dot{W}_{TUfan,05,n} = 122 \;\; [\mathrm{W}] \tag{1062}$$

$$\dot{Q}_{s,coolingTU,01,n} = \dot{Q}_{TUcoolingcoil,01,n} - \dot{W}_{TUfan,01,n} \tag{1063}$$

$$\dot{Q}_{s,coolingTU,02,n} = \dot{Q}_{TUcoolingcoil,02,n} - \dot{W}_{TUfan,02,n} \tag{1064}$$

$$\dot{Q}_{s,coolingTU,03,n} = \dot{Q}_{TUcoolingcoil,03,n} - \dot{W}_{TUfan,03,n} \tag{1065}$$

$$\dot{Q}_{s,coolingTU,04,n} = \dot{Q}_{TUcoolingcoil,04,n} - \dot{W}_{TUfan,04,n} \tag{1066}$$

$$\dot{Q}_{s,coolingTU,05,n} = \dot{Q}_{TUcoolingcoil,05,n} - \dot{W}_{TUfan,05,n} \tag{1067}$$

Water pressure drop in nominal conditions:

$$\Delta p_{w,TUcoolingcoil,n} = 0.2 \times 10^5 \;\; [\mathrm{Pa}] \tag{1068}$$

Water flow rates:

$$\dot{M}_{w,TUcoolingcoil,01,n} = \frac{\dot{Q}_{TUcoolingcoil,01,n}}{c_f \cdot (t_{w,TUcooling,ex,n} - t_{w,TUcooling,su,n})} \tag{1069}$$

$$\dot{M}_{w,TUcoolingcoil,02,n} = \frac{\dot{Q}_{TUcoolingcoil,02,n}}{c_f \cdot (t_{w,TUcooling,ex,n} - t_{w,TUcooling,su,n})} \tag{1070}$$

$$\dot{M}_{w,TUcoolingcoil,03,n} = \frac{\dot{Q}_{TUcoolingcoil,03,n}}{c_f \cdot (t_{w,TUcooling,ex,n} - t_{w,TUcooling,su,n})} \tag{1071}$$

$$\dot{M}_{w,TUcoolingcoil,04,n} = \frac{\dot{Q}_{TUcoolingcoil,04,n}}{c_f \cdot (t_{w,TUcooling,ex,n} - t_{w,TUcooling,su,n})} \tag{1072}$$

$$\dot{M}_{w,TUcoolingcoil,05,n} = \frac{\dot{Q}_{TUcoolingcoil,05,n}}{c_f \cdot (t_{w,TUcooling,ex,n} - t_{w,TUcooling,su,n})} \tag{1073}$$

Air temperature at coil supply:

$$t_{a,TUcoolingcoil,su,01,n} = t_{a,in,cooling,n} + \frac{\dot{W}_{TUfan,01,n}}{\dot{M}_{a,TUcooling,01,n} \cdot c_{p,ref}} \tag{1074}$$

$$t_{a,TUcoolingcoil,su,02,n} = t_{a,in,cooling,n} + \frac{\dot{W}_{TUfan,02,n}}{\dot{M}_{a,TUcooling,02,n} \cdot c_{p,ref}} \tag{1075}$$

$$t_{a,TUcoolingcoil,su,03,n} = t_{a,in,cooling,n} + \frac{\dot{W}_{TUfan,03,n}}{\dot{M}_{a,TUcooling,03,n} \cdot c_{p,ref}} \tag{1076}$$

$$t_{a,TUcoolingcoil,su,04,n} = t_{a,in,cooling,n} + \frac{\dot{W}_{TUfan,04,n}}{\dot{M}_{a,TUcooling,04,n} \cdot c_{p,ref}} \tag{1077}$$

$$t_{a,TUcoolingcoil,su,05,n} = t_{a,in,cooling,n} + \frac{\dot{W}_{TUfan,05,n}}{\dot{M}_{a,TUcooling,05,n} \cdot c_{p,ref}} \tag{1078}$$

Air flow rates:

$$\dot{M}_{a,TUcooling,01,n} = \frac{\dot{Q}_{s,coolingTU,01,n}}{c_{p,ref} \cdot (t_{a,in,cooling,n} - t_{a,TUcooling,ex,n})} \tag{1079}$$

$$\dot{M}_{a,TUcooling,02,n} = \frac{\dot{Q}_{s,coolingTU,02,n}}{c_{p,ref} \cdot (t_{a,in,cooling,n} - t_{a,TUcooling,ex,n})} \tag{1080}$$

$$\dot{M}_{a,TUcooling,03,n} = \frac{\dot{Q}_{s,coolingTU,03,n}}{c_{p,ref} \cdot (t_{a,in,cooling,n} - t_{a,TUcooling,ex,n})} \tag{1081}$$

$$\dot{M}_{a,TUcooling,04,n} = \frac{\dot{Q}_{s,coolingTU,04,n}}{c_{p,ref} \cdot (t_{a,in,cooling,n} - t_{a,TUcooling,ex,n})} \tag{1082}$$

$$\dot{M}_{a,TUcooling,05,n} = \frac{\dot{Q}_{s,coolingTU,05,n}}{c_{p,ref} \cdot (t_{a,in,cooling,n} - t_{a,TUcooling,ex,n})} \tag{1083}$$

Simulation model:

Outputs:

$\dot{Q}_{TUcoolingcoil}$, $t_{w,TUcooling,ex}$

Input variable:

$$t_{w,TUcooling,su} = 14 \ [C] \tag{1084}$$

(could also vary according to some control strategy)

Control inputs:

$f_{w,coolingTU}$: see § 10

gain of proportional control: $C_{coolingTU}$ see §10

set point:

$t_{in,cooling,set}$: see § 10

Parameters:

$AU_{TUcoolingcoil,n}$ and corresponding temperatures and flow rate(s)...

$$\epsilon_{mixing,coolingTU,01} = 0.95 \ [\cdot] \tag{1085}$$

$$\epsilon_{mixing,coolingTU,02} = 0.95 \ [\cdot] \tag{1086}$$

$$\epsilon_{mixing,coolingTU,03} = 0.95 \ [\cdot] \tag{1087}$$

$$\epsilon_{mixing,coolingTU,04} = 0.95 \ [\cdot] \tag{1088}$$

$$\epsilon_{mixing,coolingTU,05} = 0.95 \ [\cdot] \tag{1089}$$

related to the type of terminal unit and to its position

(might be even bigger than 1 thanks to stratification, if the unit is near the ceiling)

Air temperature at terminal unit supply:

$$t_{a,TUcooling,su,01} = t_{a,in,01} + (1 - \epsilon_{mixing,coolingTU,01}) \cdot (t_{w,TUcooling,su} - t_{a,in,01}) \tag{1090}$$

$$t_{a,TUcooling,su,02} = t_{a,in,02} + (1 - \epsilon_{mixing,coolingTU,02}) \cdot (t_{w,TUcooling,su} - t_{a,in,02}) \tag{1091}$$

$$t_{a,TUcooling,su,03} = t_{a,in,03} + (1 - \epsilon_{mixing,coolingTU,03}) \cdot (t_{w,TUcooling,su} - t_{a,in,03}) \tag{1092}$$

$$t_{a,TUcooling,su,04} = t_{a,in,04} + (1 - \epsilon_{mixing,coolingTU,04}) \cdot (t_{w,TUcooling,su} - t_{a,in,04}) \tag{1093}$$

$$t_{a,TUcooling,su,05} = t_{a,in,05} + (1 - \epsilon_{mixing,coolingTU,05}) \cdot (t_{w,TUcooling,su} - t_{a,in,05}) \tag{1094}$$

Air flow rate:

$$\dot{M}_{a,TUcooling,01} = \dot{M}_{a,TUcooling,01,n} \tag{1095}$$

$$\dot{M}_{a,TUcooling,02} = \dot{M}_{a,TUcooling,02,n} \tag{1096}$$

$$\dot{M}_{a,TUcooling,03} = \dot{M}_{a,TUcooling,03,n} \tag{1097}$$

$$\dot{M}_{a,TUcooling,04} = \dot{M}_{a,TUcooling,04,n} \tag{1098}$$

$$\dot{M}_{a,TUcooling,05} = \dot{M}_{a,TUcooling,05,n} \tag{1099}$$

Air temperature at coil supply:

$$t_{a,TUcoolingcoil,su,01} = t_{a,TUcooling,su,01} + \frac{\dot{W}_{TUfan,01}}{\dot{M}_{a,TUcooling,01} \cdot c_{p,ref}} \tag{1100}$$

$$t_{a,TUcoolingcoil,su,02} = t_{a,TUcooling,su,02} + \frac{\dot{W}_{TUfan,02}}{\dot{M}_{a,TUcooling,02} \cdot c_{p,ref}} \tag{1101}$$

$$t_{a,TUcoolingcoil,su,03} = t_{a,TUcooling,su,03} + \frac{\dot{W}_{TUfan,03}}{\dot{M}_{a,TUcooling,03} \cdot c_{p,ref}} \tag{1102}$$

$$t_{a,TUcoolingcoil,su,04} = t_{a,TUcooling,su,04} + \frac{\dot{W}_{TUfan,04}}{\dot{M}_{a,TUcooling,04} \cdot c_{p,ref}} \tag{1103}$$

$$t_{a,TUcoolingcoil,su,05} = t_{a,TUcooling,su,05} + \frac{\dot{W}_{TUfan,05}}{\dot{M}_{a,TUcooling,05} \cdot c_{p,ref}} \tag{1104}$$

Maximal heat output (with control valve fully open):

$$\dot{Q}_{TUcoolingcoil,01,max} = \dot{Q}_{TUcoolingcoil,01,n} \cdot \frac{t_{w,TUcooling,su} - t_{a,TUcoolingcoil,su,01}}{t_{w,TUcooling,su,n} - t_{a,TUcoolingcoil,su,01,n}} \tag{1105}$$

$$\dot{Q}_{TUcoolingcoil,02,max} = \dot{Q}_{TUcoolingcoil,02,n} \cdot \frac{t_{w,TUcooling,su} - t_{a,TUcoolingcoil,su,02}}{t_{w,TUcooling,su,n} - t_{a,TUcoolingcoil,su,02,n}} \tag{1106}$$

$$\dot{Q}_{TUcoolingcoil,03,max} = \dot{Q}_{TUcoolingcoil,03,n} \cdot \frac{t_{w,TUcooling,su} - t_{a,TUcoolingcoil,su,03}}{t_{w,TUcooling,su,n} - t_{a,TUcoolingcoil,su,03,n}} \tag{1107}$$

$$\dot{Q}_{TUcoolingcoil,04,max} = \dot{Q}_{TUcoolingcoil,04,n} \cdot \frac{t_{w,TUcooling,su} - t_{a,TUcoolingcoil,su,04}}{t_{w,TUcooling,su,n} - t_{a,TUcoolingcoil,su,04,n}} \tag{1108}$$

$$\dot{Q}_{TUcoolingcoil,05,max} = \dot{Q}_{TUcoolingcoil,05,n} \cdot \frac{t_{w,TUcooling,su} - t_{a,TUcoolingcoil,su,05}}{t_{w,TUcooling,su,n} - t_{a,TUcoolingcoil,su,05,n}} \tag{1109}$$

Ideal proportional feed back control and coil heat output:

$$X_{coolingTU,01} = \min\left(1,\ \max\left(0,\ C_{coolingTU} \cdot (t_{a,in,01} - t_{a,in,cooling,01,set})\right)\right) \tag{1110}$$

$$\dot{Q}_{TUcoolingcoil,01} = f_{w,coolingTU} \cdot X_{coolingTU,01} \cdot \dot{Q}_{TUcoolingcoil,01,max} \tag{1111}$$

$$X_{coolingTU,02} = \min\left(1,\ \max\left(0,\ C_{coolingTU} \cdot (t_{a,in,02} - t_{a,in,cooling,02,set})\right)\right) \tag{1112}$$

$$\dot{Q}_{TUcoolingcoil,02} = f_{w,coolingTU} \cdot X_{coolingTU,02} \cdot \dot{Q}_{TUcoolingcoil,02,max} \tag{1113}$$

$$X_{coolingTU,03} = \min\left(1,\ \max\left(0,\ C_{coolingTU} \cdot (t_{a,in,03} - t_{a,in,cooling,03,set})\right)\right) \tag{1114}$$

$$\dot{Q}_{TUcoolingcoil,03} = f_{w,coolingTU} \cdot X_{coolingTU,03} \cdot \dot{Q}_{TUcoolingcoil,03,max} \tag{1115}$$

$$X_{coolingTU,04} = \min\left(1,\ \max\left(0,\ C_{coolingTU} \cdot (t_{a,in,04} - t_{a,in,cooling,04,set})\right)\right) \tag{1116}$$

$$\dot{Q}_{TUcoolingcoil,04} = f_{w,coolingTU} \cdot X_{coolingTU,04} \cdot \dot{Q}_{TUcoolingcoil,04,max} \tag{1117}$$

$$X_{coolingTU,05} = \min\left(1,\ \max\left(0,\ C_{coolingTU} \cdot (t_{a,in,05} - t_{a,in,cooling,05,set})\right)\right) \tag{1118}$$

$$\dot{Q}_{TUcoolingcoil,05} = f_{w,coolingTU} \cdot X_{coolingTU,05} \cdot \dot{Q}_{TUcoolingcoil,05,max} \tag{1119}$$

Still in dry regime, then

$$\dot{Q}_{s,TUcoolingcoil,01} = \dot{Q}_{TUcoolingcoil,01} \tag{1120}$$

$$\dot{Q}_{s,TUcoolingcoil,02} = \dot{Q}_{TUcoolingcoil,02} \tag{1121}$$

$$\dot{Q}_{s,TUcoolingcoil,03} = \dot{Q}_{TUcoolingcoil,03} \tag{1122}$$

$$\dot{Q}_{s,TUcoolingcoil,04} = \dot{Q}_{TUcoolingcoil,04} \tag{1123}$$

$$\dot{Q}_{s,TUcoolingcoil,05} = \dot{Q}_{TUcoolingcoil,05} \tag{1124}$$

$$Q_{TUcoolingcoil,01} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUcoolingcoil,01}\,\mathrm{d}\tau \tag{1125}$$

$$Q_{TUcoolingcoil,01,kWh} = Q_{TUcoolingcoil,01}/J/kWh \tag{1126}$$

$$Q_{TUcoolingcoil,02} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUcoolingcoil,02}\,\mathrm{d}\tau \tag{1127}$$

$$Q_{TUcoolingcoil,02,kWh} = Q_{TUcoolingcoil,02}/J/kWh \tag{1128}$$

$$Q_{TUcoolingcoil,03} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUcoolingcoil,03}\,\mathrm{d}\tau \tag{1129}$$

$$Q_{TUcoolingcoil,03,kWh} = Q_{TUcoolingcoil,03}/J/kWh \tag{1130}$$

$$Q_{TUcoolingcoil,04} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUcoolingcoil,04}\,\mathrm{d}\tau \tag{1131}$$

$$Q_{TUcoolingcoil,04,kWh} = Q_{TUcoolingcoil,04}/J/kWh \tag{1132}$$

$$Q_{TUcoolingcoil,05} = \int_{\tau_1}^{\tau_2} \dot{Q}_{TUcoolingcoil,05}\,\mathrm{d}\tau \tag{1133}$$

$$Q_{TUcoolingcoil,05,kWh} = Q_{TUcoolingcoil,05}/J/kWh \tag{1134}$$

$$\dot{Q}_{TUcoolingcoils,floor} = \dot{Q}_{TUcoolingcoil,01} + \dot{Q}_{TUcoolingcoil,02} + \dot{Q}_{TUcoolingcoil,03} + \dot{Q}_{TUcoolingcoil,04} + \dot{Q}_{TUcoolingcoil,05} \tag{1135}$$

$$\dot{Q}_{TUcoolingcoils} = n_{floor} \cdot \dot{Q}_{TUcoolingcoils,floor} \tag{1136}$$

$$Q_{TUcoolingcoils,floor,kWh} = Q_{TUcoolingcoil,01,kWh} + Q_{TUcoolingcoil,02,kWh} + Q_{TUcoolingcoil,03,kWh} + Q_{TUcoolingcoil,04,kWh} + Q_{TUcoolingc}$$

$$Q_{TUcoolingcoils,kWh} = n_{floor} \cdot Q_{TUcoolingcoils,floor,kWh} \quad (1138)$$

Total heat output of the terminal unit:

$$\dot{Q}_{s,coolingTU,01} = \dot{Q}_{TUcoolingcoil,01} - \dot{W}_{TUfan,01} \quad (1139)$$

$$\dot{Q}_{s,coolingTU,02} = \dot{Q}_{TUcoolingcoil,02} - \dot{W}_{TUfan,02} \quad (1140)$$

$$\dot{Q}_{s,coolingTU,03} = \dot{Q}_{TUcoolingcoil,03} - \dot{W}_{TUfan,03} \quad (1141)$$

$$\dot{Q}_{s,coolingTU,04} = \dot{Q}_{TUcoolingcoil,04} - \dot{W}_{TUfan,04} \quad (1142)$$

$$\dot{Q}_{s,coolingTU,05} = \dot{Q}_{TUcoolingcoil,05} - \dot{W}_{TUfan,05} \quad (1143)$$

$$\dot{Q}_{s,coolingTU,floor} = \dot{Q}_{s,coolingTU,01} + \dot{Q}_{s,coolingTU,02} + \dot{Q}_{s,coolingTU,03} + \dot{Q}_{s,coolingTU,04} + \dot{Q}_{s,coolingTU,05} \quad (1144)$$

$$\dot{Q}_{s,coolingTU} = n_{floor} \cdot \dot{Q}_{s,coolingTU,floor} \quad (1145)$$

Average water flow rate (also with digital control):

$$\dot{M}_{w,TUcoolingcoil,01} = f_{w,coolingTU} \cdot X_{coolingTU,01} \cdot \dot{M}_{w,TUcoolingcoil,01,n} \quad (1146)$$

$$\dot{M}_{w,TUcoolingcoil,02} = f_{w,coolingTU} \cdot X_{coolingTU,02} \cdot \dot{M}_{w,TUcoolingcoil,02,n} \quad (1147)$$

$$\dot{M}_{w,TUcoolingcoil,03} = f_{w,coolingTU} \cdot X_{coolingTU,03} \cdot \dot{M}_{w,TUcoolingcoil,03,n} \quad (1148)$$

$$\dot{M}_{w,TUcoolingcoil,04} = f_{w,coolingTU} \cdot X_{coolingTU,04} \cdot \dot{M}_{w,TUcoolingcoil,04,n} \quad (1149)$$

$$\dot{M}_{w,TUcoolingcoil,05} = f_{w,coolingTU} \cdot X_{coolingTU,05} \cdot \dot{M}_{w,TUcoolingcoil,05,n} \quad (1150)$$

`$BOOKMARK 06. WATER DISTRIBUTION NETWORKS AND PUMPS`

6 WATER DISTRIBUTION NETWORKS AND PUMPS

6.1 Hot water distribution network:

6.1.1 Secondary network:

6.1.1.1 Preheating coil circuit:

Sizing:

$$\dot{W}_{preheatingpump,n} = \dot{M}_{w,preheatingcoil,n} \cdot v_f \cdot \frac{\Delta p_{w,preheatingcircuit,n}}{\eta_{preheatingpump,n}} \quad (1151)$$

$$\Delta p_{w,preheatingcircuit,n} = 0.25 \times 10^5 \ \text{[Pa]} \quad (1152)$$

$$\eta_{preheatingpump,n} = 0.55 \ [-] \quad (1153)$$

Simulation:

Input:

$f_{preheatingpump}$: see §10.4

$$\dot{W}_{preheatingpump} = f_{preheatingpump} \cdot \dot{W}_{preheatingpump,n} \tag{1154}$$

(because constant water flow rate)

6.1.1.2 Postheatingcoil circuit:

$$\dot{M}_{w,postheatingcircuit,n} = \dot{M}_{w,postheatingcoil,n} \tag{1155}$$

$$\Delta p_{w,postheatingcircuit,n} = 25 \times 10^3 \text{ [Pa]} \tag{1156}$$

$$\eta_{postheatingcoilpump,n} = 0.55 \; \square \tag{1157}$$

$$\dot{W}_{postheatingcoilpump,n} = \dot{M}_{w,postheatingcircuit,n} \cdot v_f \cdot \frac{\Delta p_{w,postheatingcircuit,n}}{\eta_{postheatingcoilpump,n}} \tag{1158}$$

Simulation:

Inputs:

$f_{postheatingpump}$: see § 10.4

$t_{hotopenheader,sec,ex}$: see § 6.1.1.4

Equations:

$$\dot{M}_{w,postheatingcircuit} = \dot{M}_{w,postheatingcircuit,n} \tag{1159}$$

$$t_{w,postheatingcircuit,ex} = t_{w,postheating,ex} \tag{1160}$$

$$\dot{W}_{postheatingcoilpump} = f_{postheatingpump} \cdot \dot{W}_{postheatingcoilpump,n} \tag{1161}$$

$$W_{postheatingcoilpump} = \int_{\tau_1}^{\tau_2} \dot{W}_{postheatingcoilpump} \, \mathrm{d}\tau \tag{1162}$$

$$W_{postheatingcoilpump,kWh} = W_{postheatingcoilpump} / J/kWh \tag{1163}$$

6.1.1.3 TUheatingcoils circuit:

Sizing:

$$\dot{Q}_{TUheatingcoils,n} = n_{floor} \cdot \Big(\dot{Q}_{TUheatingcoil,01,n} + \dot{Q}_{TUheatingcoil,02,n} + \dot{Q}_{TUheatingcoil,03,n} + \dot{Q}_{TUheatingcoil,04,n} + \dot{Q}_{TUheatingcoil,05}$$

$$\dot{M}_{w,TUheatingcoils,n} = n_{floor} \cdot \Big(\dot{M}_{w,TUheatingcoil,01,n} + + \dot{M}_{w,TUheatingcoil,02,n} + \dot{M}_{w,TUheatingcoil,03,n} + \dot{M}_{w,TUheatingcoil,04,n} + \dot{M}_{w}$$

$$\eta_{TUheatingpump,n} = 0.55 \; \square \tag{1166}$$

$$\Delta p_{w,TUheatingcircuit,n} = 64.1 \times 10^3 \text{ [Pa]} \tag{1167}$$

$$\dot{W}_{TUheatingpump,n} = \dot{M}_{w,TUheatingcoils,n} \cdot v_f \cdot \frac{\Delta p_{w,TUheatingcircuit,n}}{\eta_{TUheatingpump,n}} \tag{1168}$$

Simulation:

Input:

$t_{w,TUheating,su}$: see & 5.3

$f_{TUheatingpump}$: see § 10.4

$$\dot{M}_{w,TUheatingloop} = \dot{M}_{w,TUheatingcoils,n} \tag{1169}$$

$$\dot{W}_{TUheatingpump} = f_{TUheatingpump} \cdot \dot{W}_{TUheatingpump,n} \tag{1170}$$

(if constant rotation speed pump)

$$t_{w,TUheatingbypass,ex} = t_{w,TUheating,su} - \frac{\dot{Q}_{TUheatingcoils}}{\dot{M}_{w,TUheatingloop} \cdot c_f + Watt/Kelvin_{min}} \tag{1171}$$

$$t_{w,TUheatingloop,su} = t_{hotopenheader,sec,ex} \tag{1172}$$

$$t_{w,TUheatingloop,ex} = t_{w,TUheatingbypass,ex} \tag{1173}$$

$$\dot{M}_{w,TUheatingloop,su} = \frac{\dot{Q}_{TUheatingcoils} - \dot{W}_{TUheatingpump}}{(c_f \cdot (t_{w,TUheatingloop,su} - t_{w,TUheatingloop,ex}) + J/kg_{min})} \tag{1174}$$

$$X_{TUheating} = \frac{\dot{M}_{w,TUheatingloop,su}}{\dot{M}_{w,TUheatingloop} + \dot{M}_{min}} \tag{1175}$$

6.1.1.4 Open header :

Sizing:

$$Induction_{hotopenheader} = 0.1 \; [\cdot] \tag{1176}$$

Inputs:

$\dot{M}_{w,boiler}$, $t_{w,boiler,ex}$: see & 6.1.2

Simulation:

Secondary flow rate:

$$\dot{M}_{w,hotopenheader,sec} = \dot{M}_{w,preheatingloop,su} + \dot{M}_{w,postheatingcircuit} + \dot{M}_{w,TUheatingloop,su} \tag{1177}$$

Secondary side energy balance:

$$t_{hotopenheader,sec,su} = t_{hotopenheader,sec,ex} - \frac{\dot{Q}_{preheatingcoil} - \dot{W}_{preheatingpump} + \dot{Q}_{postheatingcoil} - \dot{W}_{postheatingcoilpump} + \dot{Q}_{TUheatin}}{\dot{M}_{w,hotopenheader,sec} \cdot c_f + Watt/Kelvin_{min}}$$

(if neglecting all distribution losses)

Primary flow rate:

$$\dot{M}_{w,hotopenheader,prim} = \dot{M}_{w,boiler} \tag{1179}$$

Primary side energy balance:

$$t_{hotopenheader,prim,ex} = t_{hotopenheader,prim,su} - \frac{\dot{Q}_{preheatingcoil} - \dot{W}_{preheatingpump} + \dot{Q}_{postheatingcoil} - \dot{W}_{postheatingcoilpump} + \dot{Q}_{TUhe}}{\dot{M}_{w,hotopenheader,prim} \cdot c_f + Watt/Kelvin_{min}}$$

(again, if neglecting all distribution losses)

with

$$t_{hotopenheader,prim,su} = t_{w,boiler,ex} \tag{1181}$$

Inside induction effect:

$$\dot{M}_{w,hotopenheader,recirc} = Induction_{hotopenheader} \cdot \dot{M}_{w,hotopenheader,prim} \tag{1182}$$

Mixing on primary side:

$$\dot{M}_{w,hotopenheader,prim} \cdot t_{hotopenheader,prim,su} + \dot{M}_{w,hotopenheader,recirc} \cdot t_{hotopenheader,prim,ex} = \Big(\dot{M}_{w,hotopenheader,prim} + \dot{M}_{w,hotopenhea}$$

Mixing on secondary side:

$$\Big(\dot{M}_{w,hotopenheader,prim} + \dot{M}_{w,hotopenheader,recirc} - \dot{M}_{hotopenheader,sec}\Big) \cdot t_{hotopenheader,sec,ex} + \dot{M}_{w,hotopenheader,sec} \cdot t_{hotopenheader,sec,s}$$

———————————-

6.1.2 Primary network:

Sizing:

Sizing outputs:

$\dot{Q}_{heatdistributionloss,n}$, $\dot{Q}_{boiler,n}$, $\dot{M}_{w,boiler,n}$, D, AU, $\Delta p_{w,boilercircuit,n}$, $\dot{W}_{boilerpump,n}$

Sizing inputs:

$\dot{Q}_{heating,n}$

Oversizing factor:

$$F_{boiler,oversizing} = 1\ [\,] \tag{1185}$$

$$t_{w,boiler,ex,n} = 70\ [\mathrm{C}] \tag{1186}$$

$$t_{w,boiler,su,n} = 50\ [\mathrm{C}] \tag{1187}$$

Equations:

$$\dot{Q}_{boiler,n} = F_{boiler,oversizing} \cdot \Big(\dot{Q}_{preheatingcoil,n} + \dot{Q}_{postheatingcoil,n} + \dot{Q}_{TUheatingcoils,n}\Big) \tag{1188}$$

(fair estimate)

$$\dot{M}_{w,boiler,n} = \frac{\dot{Q}_{boiler,n}}{c_f \cdot (t_{w,boiler,ex,n} - t_{w,boiler,su,n})} \tag{1189}$$

$$\Delta p_{w,boilercircuit,n} = 30 \times 10^3\ [\mathrm{Pa}] \tag{1190}$$

(could be determined by pressure drop calculation)

$$\eta_{boilerpump,n} = 0.55\ [\,] \tag{1191}$$

$$\dot{W}_{boilerpump,n} = \dot{M}_{w,boiler,n} \cdot v_f \cdot \frac{\Delta p_{w,boilercircuit,n}}{\eta_{boilerpump,n}} \tag{1192}$$

———————————-

Simulation:

Hypothesis: constant water flow rate in boiler loop

Outputs:

$\dot{Q}_{boiler}$, $t_{w,boiler,su}$ $\dot{M}_{w,boiler}$, $\Delta p_{w,boilercircuit}$, $\dot{W}_{boilerpump}$

Inputs:

$f_{boilerpump}$: see § 10

$\dot{Q}_{heating}$

$$t_{w,boiler,ex} = 70 \ [\mathrm{C}] \tag{1193}$$

(could also vary according to some control stratgy)

$t_{hotopenheader,prim,ex}$

Equations:

$$\dot{M}_{w,boiler} = \dot{M}_{w,boiler,n} \tag{1194}$$

$$\Delta p_{w,boilercircuit} = \Delta p_{w,boilercircuit,n} \tag{1195}$$

$$\eta_{boilerpump} = \eta_{boilerpump,n} \tag{1196}$$

$$\dot{W}_{boilerpump} = f_{boilerpump} \cdot \dot{W}_{boilerpump,n} \tag{1197}$$

$$W_{boilerpump} = \int_{\tau_1}^{\tau_2} \dot{W}_{boilerpump} \, \mathrm{d}\tau \tag{1198}$$

$$W_{boilerpump,kWh} = W_{boilerpump}/J/kWh \tag{1199}$$

$$t_{w,boiler,su} = t_{hotopenheader,prim,ex} + \frac{\dot{W}_{boilerpump}}{c_f \cdot \dot{M}_{w,boiler}} \tag{1200}$$

$\dot{Q}_{boiler}$=max(0,c_f*$\dot{M}_{w,boiler}$*($t_{w,boiler,ex}$-$t_{w,boiler,su}$))

$$\dot{Q}_{boiler} = \dot{Q}_{preheatingcoil} + \dot{Q}_{postheatingcoil} + \dot{Q}_{TUheatingcoils} - \dot{W}_{heatingpumps} \tag{1201}$$

————————

6.2 Cold water distribution network:

6.2.1 Secondary network:

6.2.1.1 Coolingcoil circuit:

$$\dot{M}_{w,Coolingcoilcircuit,n} = \dot{M}_{w,Coolingcoil,n} \tag{1202}$$

$$\Delta p_{w,Coolingcoilcircuit,n} = 0.5 \times 10^5 \ [\mathrm{Pa}] \tag{1203}$$

$$\eta_{Coolingcoilpump,n} = 0.55 \ [-] \tag{1204}$$

$$\dot{W}_{Coolingcoilpump,n} = \dot{M}_{w,Coolingcoilcircuit,n} \cdot v_f \cdot \frac{\Delta p_{w,Coolingcoilcircuit,n}}{\eta_{Coolingcoilpump,n}} \tag{1205}$$

Simulation:

Inputs:

$f_{Coolingpump}$: see § 10.4

$t_{coldopenheader,sec,ex}$: see § 6.2.1.3

Equations:

$$\dot{M}_{w,Coolingcoilcircuit} = \dot{M}_{w,Coolingcoilcircuit,n} \tag{1206}$$

$$t_{w,Coolingcoilcircuit,ex} = t_{w,coolingcoil,ex} \tag{1207}$$

$$\dot{W}_{Coolingcoilpump} = f_{Coolingcoilpump} \cdot \dot{W}_{Coolingcoilpump,n} \tag{1208}$$

$$W_{Coolingcoilpump} = \int_{\tau_1}^{\tau_2} \dot{W}_{Coolingcoilpump} \, \mathrm{d}\tau \tag{1209}$$

$$W_{Coolingcoilpump,kWh} = W_{Coolingcoilpump}/J/kWh \tag{1210}$$

6.2.1.2 TUCoolingcoils circuit:

Sizing:

$$\dot{Q}_{TUCoolingcoils,n} = n_{floor} \cdot \Big(\dot{Q}_{TUCoolingcoil,01,n} + \dot{Q}_{TUCoolingcoil,02,n} + \dot{Q}_{TUCoolingcoil,03,n} + \dot{Q}_{TUCoolingcoil,04,n} + \dot{Q}_{TUCoolingcoil,0}$$

$$\dot{M}_{w,TUCoolingcoils,n} = n_{floor} \cdot \Big(\dot{M}_{w,TUCoolingcoil,01,n} + \dot{M}_{w,TUCoolingcoil,02,n} + \dot{M}_{w,TUCoolingcoil,03,n} + \dot{M}_{w,TUCoolingcoil,04,n} + \dot{M}_{w,}$$

$$\eta_{TUCoolingpump,n} = 0.55 \ [\cdot] \tag{1213}$$

$$\Delta p_{w,TUCoolingcircuit,n} = 0.8 \times 10^5 \ \text{[Pa]} \tag{1214}$$

$$\dot{W}_{TUCoolingpump,n} = \dot{M}_{w,TUCoolingcoils,n} \cdot v_f \cdot \frac{\Delta p_{w,TUCoolingcircuit,n}}{\eta_{TUCoolingpump,n}} \tag{1215}$$

Simulation:

Input:

$t_{w,TUCooling,su}$: see & 5.2

$f_{TUCoolingpump}$: see § 10.4

Equations:

$$\dot{M}_{w,TUCoolingloop} = \dot{M}_{w,TUCoolingcoils,n} \tag{1216}$$

$$\dot{W}_{TUCoolingpump} = f_{TUCoolingpump} \cdot \dot{W}_{TUCoolingpump,n} \tag{1217}$$

(if constant rotation speed pump)

$$t_{w,TUCoolingloop,su} = t_{coldopenheader,sec,ex} \tag{1218}$$

$$t_{w,TUCoolingbypass,ex} = t_{w,TUCooling,su} + \frac{\dot{Q}_{TUCoolingcoils}}{\dot{M}_{w,TUCoolingloop} \cdot c_f + Watt/Kelvin_{min}} \tag{1219}$$

$$t_{w,TUCoolingloop,ex} = t_{w,TUCoolingbypass,ex} \quad (1220)$$

$$\dot{M}_{w,TUCoolingloop,su} = \frac{\dot{Q}_{TUCoolingcoils} + \dot{W}_{TUCoolingpump}}{(c_f \cdot (t_{w,TUCoolingloop,ex} - t_{w,TUCoolingloop,su}) + J/kg_{min})} \quad (1221)$$

$$X_{TUCooling} = \frac{\dot{M}_{w,TUCoolingloop,su}}{\dot{M}_{w,TUCoolingloop} + \dot{M}_{min}} \quad (1222)$$

6.2.1.3 Cold open header :

Sizing:

$$Induction_{Coldopenheader} = 0.1 \ [-] \quad (1223)$$

Inputs:

$\dot{M}_{w,chiller}$, $t_{w,chiller,ex}$: see & 6.2.2

Simulation:

Secondary flow rate:

$$\dot{M}_{w,Coldopenheader,sec} = \dot{M}_{w,coolingcoilcircuit} + \dot{M}_{w,TUcoolingloop,su} \quad (1224)$$

Secondary side energy balance:

$$t_{Coldopenheader,sec,su} = t_{Coldopenheader,sec,ex} + \frac{\dot{Q}_{coolingcoil} + \dot{W}_{Coolingcoilpump} + \dot{Q}_{TUCoolingcoils} + \dot{W}_{TUCoolingpump}}{\dot{M}_{w,Coldopenheader,sec} \cdot c_f + Watt/Kelvin_{min}} \quad (1225)$$

(if neglecting all distribution heat gains)

Primary flow rate:

$$\dot{M}_{w,Coldopenheader,prim} = \dot{M}_{w,evaporators} \quad (1226)$$

Primary side energy balance:

$$t_{Coldopenheader,prim,ex} = t_{Coldopenheader,prim,su} + \frac{\dot{Q}_{coolingcoil} + \dot{W}_{Coolingcoilpump} + \dot{Q}_{TUCoolingcoils} + \dot{W}_{TUCoolingpump}}{\dot{M}_{w,Coldopenheader,prim} \cdot c_f + Watt/Kelvin_{min}} \quad (1227)$$

(again, if neglecting all distribution heat gains)

with

$$t_{Coldopenheader,prim,su} = t_{w,evaporators,ex} \quad (1228)$$

Inside induction effect:

$$\dot{M}_{w,Coldopenheader,recirc} = Induction_{Coldopenheader} \cdot \dot{M}_{w,Coldopenheader,prim} \quad (1229)$$

Mixing on primary side:

$$\dot{M}_{w,Coldopenheader,prim} \cdot t_{Coldopenheader,prim,su} + \dot{M}_{w,Coldopenheader,recirc} \cdot t_{Coldopenheader,prim,ex} = \left(\dot{M}_{w,Coldopenheader,prim} + \dot{M}_{w,Col}\right.$$

Mixing on secondary side:

$$\left(\dot{M}_{w,Coldopenheader,prim} + \dot{M}_{w,Coldopenheader,recirc} - \dot{M}_{Coldopenheader,sec}\right) \cdot t_{Coldopenheader,sec,ex} + \dot{M}_{w,Coldopenheader,sec} \cdot t_{Coldopenhea}$$

—————————————-

6.2.2 Primary network:

Sizing:

Sizing inputs:

$\dot{Q}_{cooling,n}$

Oversizing factor:

$$F_{chiller,oversizing} = 1 \; [\text{-}] \tag{1232}$$

Chilled water temperatures:

$$t_{w,evaporators,ex,n} = 7 \; [\text{C}] \tag{1233}$$

$$t_{w,evaporators,su,n} = 12 \; [\text{C}] \tag{1234}$$

Equations:

$$\dot{Q}_{evaporators,n} = F_{chiller,oversizing} \cdot \left(\dot{Q}_{Coolingcoil,n} + \dot{Q}_{TUCoolingcoils,n}\right) \tag{1235}$$

(fair estimate)

$$\dot{M}_{w,evaporators,n} = \frac{\dot{Q}_{evaporators,n}}{c_f \cdot (t_{w,evaporators,su,n} - t_{w,evaporators,ex,n})} \tag{1236}$$

$$\Delta p_{w,evaporatorcircuit,n} = 0.7 \times 10^5 \; [\text{Pa}] \tag{1237}$$

(see example: 2 machines Carrier 30RB522 in parallel)

$$\eta_{evaporatorspumps,n} = 0.55 \; [\text{-}] \tag{1238}$$

$$\dot{W}_{evaporatorspumps,n} = \dot{M}_{w,evaporators,n} \cdot v_f \cdot \frac{\Delta p_{w,evaporatorcircuit,n}}{\eta_{evaporatorspumps,n}} \tag{1239}$$

—————————————-

Simulation:

Inputs:

$\mathbf{f}_{evaporatorspumps}$: see § 10

$\dot{Q}_{cooling}$

$$t_{w,evaporators,ex} = 6 \; [\text{C}] \tag{1240}$$

(could also vary)

Calculation:

$$\dot{M}_{w,evaporators} = \dot{M}_{w,evaporators,n} \tag{1241}$$

$$\dot{W}_{evaporatorspumps} = f_{evaporatorspumps} \cdot \dot{W}_{evaporatorspumps,n} \tag{1242}$$

$$\dot{Q}_{evaporators} = \dot{Q}_{coolingcoil} + \dot{W}_{Coolingcoilpump} + \dot{Q}_{TUCoolingcoils} + \dot{W}_{TUCoolingpump} + \dot{W}_{evaporatorspumps} \tag{1243}$$

$$t_{w,evaporators,su} = t_{w,evaporators,ex} + \frac{\dot{Q}_{evaporators}}{c_f \cdot \dot{M}_{w,evaporators}} \tag{1244}$$

$$W_{evaporatorspumps} = \int_{\tau_1}^{\tau_2} \dot{W}_{evaporatorspumps} \, \mathrm{d}\tau \tag{1245}$$

$$W_{evaporatorspumps,kWh} = W_{evaporatorspumps}/J/kWh \tag{1246}$$

---

7 PLANTS

7.1 Space heating boiler simulation

Output:

$\dot{Q}_{boiler,consumed}$

Parameter:

$\dot{Q}_{boiler,n}$: see §6.1.2

$\dot{M}_{w,boiler,n}$: see §6.1.2

Inputs:

$\dot{Q}_{boiler}$: see § 6.1.2

$t_{w,boiler,su}$: see § 6.1.2

$\dot{M}_{w,boiler}$: see §6.1.2

Simulation:

$$partial_{load} = \dot{Q}_{boiler}/\dot{Q}_{boiler,n} \tag{1247}$$

$$Flowratefraction = \dot{M}_{w,boiler}/\dot{M}_{w,boiler,n} \tag{1248}$$

Boiler efficiency, parallel interpolation for different partial loads

$$Efficiency_{Power30\%} = \text{Interpolate2dm('Power 30\%'}, \ Flowratefraction, \ t_{w,boiler,su}) \tag{1249}$$

$$Efficiency_{Power45\%} = \text{Interpolate2dm('Power 45\%'}, \ Flowratefraction, \ t_{w,boiler,su}) \tag{1250}$$

$$Efficiency_{Power60\%} = \text{Interpolate2dm('Power 60\%'}, \ Flowratefraction, \ t_{w,boiler,su}) \tag{1251}$$

$$Efficiency_{Power80\%} = \text{Interpolate2dm('Power 80\%'}, \ Flowratefraction, \ t_{w,boiler,su}) \tag{1252}$$

$$Efficiency_{Power100\%} = \text{Interpolate2dm('Power 100\%'}, \ Flowratefraction, \ t_{w,boiler,su}) \tag{1253}$$

Final interpolation

$$\eta_{boiler,HHV} = \text{If}\Big(partial_{load}, \ 1, \ \text{If}\Big(partial_{load}, \ 0.8, \ \text{If}\Big(partial_{load}, \ 0.6, \ \text{If}\Big(partial_{load}, \ 0.45, \ \text{If}\Big(partial_{load}, \ 0.3, \ Efficiency_{Po}$$

Consumption:

$$\dot{Q}_{boiler,consumed} = \max\left(0, \ \dot{Q}_{boiler}/\eta_{boiler,HHV}\right) \tag{1255}$$

$$Q_{boiler,consumed} = \int_{\tau_1}^{\tau_2} \dot{Q}_{boiler,consumed} \, d\tau \quad (1256)$$

$$Q_{boiler,consumed,kWh} = Q_{boiler,consumed} / J/kWh \quad (1257)$$

Useful production:

$$Q_{boiler} = \int_{\tau_1}^{\tau_2} \dot{Q}_{boiler} \, d\tau \quad (1258)$$

$$Q_{boiler,kWh} = Q_{boiler} / J/kWh \quad (1259)$$

Average efficiency on the period considered:

$$\eta_{boiler,HHV,average} = \max\left(0, \frac{Q_{boiler}}{Q_{boiler,consumed} + 0.001}\right) \quad (1260)$$

7.2 Chiller simulation:

With air-cooled condenser

Reference: Carrier 30RB522

Outputs:

Part load ratio, electrical power and COP

Parameters:

Nominal temperatures (at design conditions), corresponding nominal cooling capacity and nominal electrical power:

$$Temp_{Evap,ex,Design} = 7 \ [\text{C}] \quad (1261)$$

$$Temp_{Cond,su,Design} = 25 \ [\text{C}] \quad (1262)$$

$$NominalCapacity/chiller = 564 \ [\text{kW}] \quad (1263)$$

$$NominalFullLoadPower/chiller = 162 \ [\text{kW}] \quad (1264)$$

with three chillers in parallel:

$$n_{chillers} = 2 \ [-] \quad (1265)$$

$$NominalCapacity = n_{chillers} \cdot NominalCapacity/chiller \quad (1266)$$

$$NominalFullLoadPower = n_{chillers} \cdot NominalFullLoadPower/chiller \quad (1267)$$

Inputs:

Temperatures of secondary fluids (water and air) at evaporator exhaust and condenser supply, cooling power (limited to the cooling capacity of the machine at temperatures considered):

$$Temp_{Evap,ex} = t_{w,evaporators,ex} \quad (1268)$$

$$Temp_{Cond,su} = t_{out} \quad (1269)$$

$$\dot{Q}_{cooling,kW} = \dot{Q}_{evaporators} / Watt/kWatt \quad (1270)$$

Simulation model:

Differences among actual and design temperatures:

$$\Delta_{temp,Cond,su} = Temp_{Cond,su} - Temp_{Cond,su,Design} \tag{1271}$$

$$\Delta_{temp,Evap,ex} = Temp_{Evap,ex} - Temp_{Evap,ex,Design} \tag{1272}$$

Temperature rise coefficient to be used for calculating the available cooling capacity ratio:

$$TempRiseCoefficient_1 = 2.694 \tag{1273}$$

Global effect of both temperature variations (at condenser supply and at evaporator exhaust):

$$\Delta_{temp,1} = \frac{\Delta_{temp,Cond,su}}{TempRiseCoefficient_1} - \Delta_{temp,Evap,ex} \tag{1274}$$

Regression coefficients to be used for calculating the available cooling capacity ratio:

$$C11 = 1 \ [-] \tag{1275}$$

$$C12 = -0.03 \ \left[\mathrm{K^{-1}}\right] \tag{1276}$$

Available cooling capacity ratio:

$$AvailToNominalCapacityRatio = C11 + C12 \cdot \Delta_{temp,1} \tag{1277}$$

Available cooling capacity:

$$AvailableCapacity = AvailToNominalCapacityRatio \cdot NominalCapacity \tag{1278}$$

Temperature rise coefficient to be used for calculating the full load power ratio:

$$TempRiseCoefficient_2 = -0.6173 \tag{1279}$$

Global effect of both temperature variations (at condenser supply and at evaporator exhaust):

$$\Delta_{temp,2} = \frac{\Delta_{temp,Cond,su}}{TempRiseCoefficient_2} - \Delta_{temp,Evap,ex} \tag{1280}$$

Regression coefficients to be used for calculating the full load electrical power ratio:

$$C21 = 1 \ [-] \tag{1281}$$

$$C22 = -0.01238 \ \left[\mathrm{K^{-1}}\right] \tag{1282}$$

Full load electrical power ratio:

$$FullLoadPowerRatio = C21 + C22 \cdot \Delta_{temp,2} \tag{1283}$$

Nominal COP:

$$NominalCOP = NominalCapacity/NominalFullLoadPower \tag{1284}$$

Actual full load electrical power (in actual conditions):

$$FullLoadPower = FullLoadPowerRatio \cdot NominalFullLoadPower \tag{1285}$$

Part load ratio:

$$PartLoadRatio = \dot{Q}_{cooling,kW} / AvailableCapacity \tag{1286}$$

Regression coefficients to be used for calculating the fraction of full load electrical power:

$$C31 = 0.100 \tag{1287}$$

$$C32 = 0.275 \tag{1288}$$

$$C33 = 0.625 \tag{1289}$$

Fraction of full load power:

$$FracFullLoadPower = C31 + C32 \cdot PartLoadRatio + C33 \cdot PartLoadRatio^2 \tag{1290}$$

Actual electrical power consumed by the chiller:

$$\dot{W}_{kW} = FracFullLoadPower \cdot FullLoadPower \tag{1291}$$

Actual COP:

$$COP = \dot{Q}_{cooling,kW} / \dot{W}_{kW} \tag{1292}$$

$$\dot{W}_{chillers} = \dot{Q}_{evaporators} / COP \tag{1293}$$

$$W_{chillers} = \int_{\tau_1}^{\tau_2} \dot{W}_{chillers} \, \mathrm{d}\tau \tag{1294}$$

$$W_{chillers,kWh} = W_{chillers} / J/kWh \tag{1295}$$

Cold production:

$$Q_{evaporators} = \int_{\tau_1}^{\tau_2} \dot{Q}_{evaporators} \, \mathrm{d}\tau \tag{1296}$$

$$Q_{evaporators,kWh} = Q_{evaporators} / J/kWh \tag{1297}$$

Average COP on the period considered:

$$COP_{average} = \frac{Q_{evaporators}}{W_{chillers} + 0.001} \tag{1298}$$

---

8 TOTAL CONSUMPTIONS

8.1. Water:

$$\dot{M}_{w,total} = \dot{M}_{w,adiabhum} \tag{1299}$$

$$M_{w,total} = M_{w,adiabhum} \tag{1300}$$

8.2. Electricity:

$$\dot{W}_{heatingpumps} = \dot{W}_{preheatingpump} + \dot{W}_{postheatingcoilpump} + \dot{W}_{TUheatingpump} + \dot{W}_{boilerpump} \tag{1301}$$

$$W_{heatingpumps} = \int_{\tau_1}^{\tau_2} \dot{W}_{heatingpumps} \, \mathrm{d}\tau \tag{1302}$$

$$W_{heatingpumps,kWh} = W_{heatingpumps} / J/kWh \tag{1303}$$

$$\dot{W}_{coolingpumps} = \dot{W}_{TUCoolingpump} + \dot{W}_{Coolingcoilpump} + \dot{W}_{evaporatorspumps} \tag{1304}$$

$$W_{coolingpumps} = \int_{\tau_1}^{\tau_2} \dot{W}_{coolingpumps} \, \mathrm{d}\tau \tag{1305}$$

$$W_{coolingpumps,kWh} = W_{coolingpumps} / J/kWh \tag{1306}$$

$$\dot{W}_{total} = \dot{W}_{light} + \dot{W}_{appl} + \dot{W}_{returnfan} + \dot{W}_{recovery} + \dot{W}_{heatingpumps} + \dot{W}_{coolingpumps} + \dot{W}_{mainfan} + \dot{W}_{TUfans} + \dot{W}_{chillers} \tag{1307}$$

$$W_{total,kWh} = W_{light,kWh} + W_{appl,kWh} + W_{returnfan,kWh} + W_{recovery,kWh} + W_{heatingpumps,kWh} + W_{coolingpumps,kWh} + W_{mainfan,kWh}$$

8.3. Gas:

$$\dot{Q}_{gas,consumed} = \dot{Q}_{boiler,consumed} \tag{1309}$$

$$Q_{gas,consumed,kWh} = Q_{boiler,consumed,kWh} \tag{1310}$$

---

9. CLIMATE AND WEATHER

$$F_{south} = \textbf{Interpolate1}(\textbf{`sun\_data'}, \textbf{`South'}, \textbf{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1311}$$

$$F_{west} = \textbf{Interpolate1}(\textbf{`sun\_data'}, \textbf{`West'}, \textbf{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1312}$$

$$F_{east} = \textbf{Interpolate1}(\textbf{`sun\_data'}, \textbf{`East'}, \textbf{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1313}$$

$$F_{north} = \textbf{Interpolate1}(\textbf{`sun\_data'}, \textbf{`North'}, \textbf{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1314}$$

p_{atm}=101325 [Pa]

$$p_{atm} = \text{Interpolate1}(\text{`frankfurt weather'}, \text{`atmos pressure'}, \text{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1315}$$

t_{out}=30 [C]

$$t_{out} = \text{Interpolate1}(\text{`frankfurt weather'}, \text{`dry bulb'}, \text{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1316}$$

RH_{out}=0.5

$$RH_{out} = \frac{\text{Interpolate1}(\text{`frankfurt weather'}, \text{`relative humidity'}, \text{`tau\_winter'}, \tau_{winter} = \tau_{winter})}{percent} \tag{1317}$$

I_{glob}=869

$$I_{glob} = \text{Interpolate1}(\text{`frankfurt weather'}, \text{`global horizontal radiation'}, \text{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1318}$$

I_{diff}=143

$$I_{diff} = \text{Interpolate1}(\text{`frankfurt weather'}, \text{`diffuse horizontal radiation'}, \text{`tau\_winter'}, \tau_{winter} = \tau_{winter}) \tag{1319}$$

---

10. COMMAND AND CONTROL VARIABLES

10.1 Occupancy

$$f_{occ,weekday} = \text{Interpolate1}(\text{'occupancy schedules'}, \text{'hour'}, \text{'f\_occ\_weekday'}, \text{'hour'} = hour_{per}) \tag{1320}$$

$$f_{occ,saturday} = \text{Interpolate1}(\text{'occupancy schedules'}, \text{'hour'}, \text{'f\_occ\_saturday'}, \text{'hour'} = hour_{per}) \tag{1321}$$

$$f_{occ,otherdays} = \text{Interpolate1}(\text{'occupancy schedules'}, \text{'hour'}, \text{'f\_occ\_otherdays'}, \text{'hour'} = hour_{per}) \tag{1322}$$

$$f_{occ} = \text{If}(day_{per}, 6, f_{occ,weekday}, f_{occ,saturday}, f_{occ,otherdays}) \tag{1323}$$

$$f_{occ,01} = f_{occ} \tag{1324}$$

$$f_{occ,02} = f_{occ} \tag{1325}$$

$$f_{occ,03} = f_{occ} \tag{1326}$$

$$f_{occ,04} = f_{occ} \tag{1327}$$

$$f_{occ,05} = f_{occ} \tag{1328}$$

10.2 Lighting

$$f_{light,weekday} = \text{Interpolate1}(\text{'lighting schedules'}, \text{'hour'}, \text{'f\_light\_weekday'}, \text{'hour'} = hour_{per}) \tag{1329}$$

$$f_{light,saturday} = \text{Interpolate1}(\text{'lighting schedules'}, \text{'hour'}, \text{'f\_light\_saturday'}, \text{'hour'} = hour_{per}) \tag{1330}$$

$$f_{light,otherdays} = \text{Interpolate1}(\text{'lighting schedules'}, \text{'hour'}, \text{'f\_light\_otherdays'}, \text{'hour'} = hour_{per}) \tag{1331}$$

$$f_{light} = \text{If}(day_{per}, 6, f_{light,weekday}, f_{light,saturday}, f_{light,otherdays}) \tag{1332}$$

$$f_{light,01} = f_{light} \tag{1333}$$

$$f_{light,02} = f_{light} \tag{1334}$$

$$f_{light,03} = f_{light} \tag{1335}$$

$$f_{light,04} = f_{light} \tag{1336}$$

$$f_{light,05} = f_{light} \tag{1337}$$

10.3 Appliances:

$$f_{equipment,weekday} = \text{Interpolate1}(\text{'equipment schedules'}, \text{'hour'}, \text{'f\_equipment\_weekday'}, \text{'hour'} = hour_{per}) \tag{1338}$$

$$f_{equipment,saturday} = \text{Interpolate1}(\text{'equipment schedules'}, \text{'hour'}, \text{'f\_equipment\_saturday'}, \text{'hour'} = hour_{per}) \tag{1339}$$

$$f_{equipment,otherdays} = \text{Interpolate1}(\text{'equipment schedules'}, \text{'hour'}, \text{'f\_equipment\_otherdays'}, \text{'hour'} = hour_{per}) \tag{1340}$$

$$f_{appl} = \text{If}(day_{per}, 6, f_{equipment,weekday}, f_{equipment,saturday}, f_{equipment,otherdays}) \tag{1341}$$

$$f_{appl,01} = f_{appl} \tag{1342}$$

$$f_{appl,02} = f_{appl} \tag{1343}$$

$$f_{appl,03} = f_{appl} \tag{1344}$$

$$f_{appl,04} = f_{appl} \tag{1345}$$

$$f_{appl,05} = f_{appl} \tag{1346}$$

10.4 Ventilation and air handling unit

Ventilation:

$$f_{ventilation} = \text{If}(f_{occ},\ 0.1,\ 0.0001,\ 1,\ 1) \tag{1347}$$

$$f_{ventilation,01} = f_{ventilation} \tag{1348}$$

$$f_{ventilation,02} = f_{ventilation} \tag{1349}$$

$$f_{ventilation,03} = f_{ventilation} \tag{1350}$$

$$f_{ventilation,04} = f_{ventilation} \tag{1351}$$

$$f_{ventilation,05} = f_{ventilation} \tag{1352}$$

$$f_{mainfan} = \text{If}(f_{occ},\ 0.1,\ 0,\ 1,\ 1) \tag{1353}$$

$$f_{returnfan} = f_{mainfan} \tag{1354}$$

$$f_{AHU} = f_{mainfan} \tag{1355}$$

$$f_{recovery} = 1\ [\cdot] \tag{1356}$$

$$X_{fresh,econo} = 1\ [\cdot] \tag{1357}$$

$$f_{preheatingcoil} = f_{AHU} \cdot \text{If}(t_{out},\ 12,\ 1,\ 1,\ 0) \tag{1358}$$

$$f_{preheatingpump} = f_{preheatingcoil} \tag{1359}$$

t$_{a,preheatingcoil,ex,set}$=10 [C]

(fixed if no adiabatic humidification)

$$f_{adiabhum} = f_{preheatingcoil} \tag{1360}$$

$$t_{a,adiabhum,ex,set} = 12\ [\text{C}] \tag{1361}$$

$$f_{coolingcoil} = f_{AHU} \cdot \text{If}(t_{out},\ 16,\ 0,\ 0,\ 1) \tag{1362}$$

$$t_{a,coolingcoil,ex,set} = 16\ [\text{C}] \tag{1363}$$

$$f_{postheatingcoil} = f_{AHU} \tag{1364}$$

$$f_{postheatingpump} = f_{postheatingcoil} \tag{1365}$$

$$t_{a,postheatingcoil,ex,set} = 16\ [\text{C}] \tag{1366}$$

$$f_{electricalhumidification} = 0\ [\cdot] \tag{1367}$$

$$f_{centralizedsteamproduction} = 0\ [\cdot] \tag{1368}$$

$$\omega_{steamhumidifier,ex,set} = 0.008\ [\cdot] \tag{1369}$$

10.5 Terminal units

$$f_{TUfan} = \text{If}(f_{occ},\ 0.1,\ 0.0001,\ 1,\ 1) \tag{1370}$$

f$_{TUfan}$=1 [-]

$$f_{w,heatingTU} = \text{If}(f_{occ},\ 0.1,\ 0.0001,\ 1,\ 1) \tag{1371}$$

f$_{w,heatingTU}$=1 [-]

$$C_{heatingTU} = 1 \ \left[\mathrm{K^{-1}}\right] \quad (1372)$$

$$heatingset_{weekday} = \text{Interpolate1}(\text{‘heating set point schedules’ , ‘hour’ , ‘heatingset\_weekday’ , ‘hour’ } = hour_{per}) \quad (1373)$$

$$heatingset_{saturday} = \text{Interpolate1}(\text{‘heating set point schedules’ , ‘hour’ , ‘heatingset\_saturday’ , ‘hour’ } = hour_{per}) \quad (1374)$$

$$heatingset_{otherdays} = \text{Interpolate1}(\text{‘heating set point schedules’ , ‘hour’ , ‘heatingset\_otherdays’ , ‘hour’ } = hour_{per}) \quad (1375)$$

$$heatingsetpoint = \text{If}\left(day_{per},\ 6,\ heatingset_{weekday},\ heatingset_{saturday},\ heatingset_{otherdays}\right) \quad (1376)$$

$$t_{a,in,heating,01,set} = heatingsetpoint \quad (1377)$$

$$t_{a,in,heating,02,set} = heatingsetpoint \quad (1378)$$

$$t_{a,in,heating,03,set} = heatingsetpoint \quad (1379)$$

$$t_{a,in,heating,04,set} = heatingsetpoint \quad (1380)$$

$$t_{a,in,heating,05,set} = heatingsetpoint \quad (1381)$$

$$f_{w,coolingTU} = \text{If}(f_{occ},\ 0.1,\ 0.0001,\ 1,\ 1) \quad (1382)$$

f$_{w,coolingTU}$=1 [-]

$$C_{coolingTU} = 1 \ \left[\mathrm{K^{-1}}\right] \quad (1383)$$

$$coolingset_{weekday} = \text{Interpolate1}(\text{‘cooling set point schedules’ , ‘hour’ , ‘coolingset\_weekday’ , ‘hour’ } = hour_{per}) \quad (1384)$$

$$coolingset_{saturday} = \text{Interpolate1}(\text{‘cooling set point schedules’ , ‘hour’ , ‘coolingset\_saturday’ , ‘hour’ } = hour_{per}) \quad (1385)$$

$$coolingset_{otherdays} = \text{Interpolate1}(\text{‘cooling set point schedules’ , ‘hour’ , ‘coolingset\_otherdays’ , ‘hour’ } = hour_{per}) \quad (1386)$$

$$coolingsetpoint = \text{If}\left(day_{per},\ 6,\ coolingset_{weekday},\ coolingset_{saturday},\ coolingset_{otherdays}\right) \quad (1387)$$

$$t_{a,in,cooling,01,set} = coolingsetpoint \quad (1388)$$

$$t_{a,in,cooling,02,set} = coolingsetpoint \quad (1389)$$

$$t_{a,in,cooling,03,set} = coolingsetpoint \quad (1390)$$

$$t_{a,in,cooling,04,set} = coolingsetpoint \quad (1391)$$

$$t_{a,in,cooling,05,set} = coolingsetpoint \quad (1392)$$

10.6 Primary units and pumps

$$f_{preheatingpump,n} = f_{AHU} \quad (1393)$$

$$f_{postheatingcoilpump} = f_{AHU} \quad (1394)$$

$$f_{coolingcoilpump} = f_{AHU} \quad (1395)$$

$$f_{TUheatingpump} = f_{w,heatingTU} \quad (1396)$$

$$f_{AHUheatingpump} = f_{AHU} \quad (1397)$$

$$f_{boilerpump} = 1 \ [\text{-}] \quad (1398)$$

$$f_{TUcoolingpump} = f_{w,coolingTU} \tag{1399}$$

$$f_{AHUcoolingpump} = f_{AHU} \tag{1400}$$

$$f_{evaporatorspumps} = 1 \tag{1401}$$

$$f_{steamboiler} = 0 \tag{1402}$$

---

11. TIME:

$$\tau - \tau_1 = (\tau_{winter} - \tau_{winter,1}) \cdot s/h \tag{1403}$$

$$\tau_1 = \tau_{winter,1} \cdot s/h \tag{1404}$$

$$\tau_2 = \tau_{winter,2} \cdot s/h \tag{1405}$$

$$\Delta\tau = \Delta\tau_{winter} \cdot s/h \tag{1406}$$

Day hour:

$$hour_{per,1} = \tau_{winter} - \text{Trunc}(\tau_{winter}/hour/day) \cdot hourday \tag{1407}$$

$$hour_{per} = \text{If}(hour_{per,1},\ 0.0000001,\ 24,\ 24,\ hour_{per,1}) \tag{1408}$$

Day:

$$day = \tau_{winter}/hour/day \tag{1409}$$

$$day_1 = \text{Trunc}(\tau_{winter}/hour/day) + 1 \cdot d \tag{1410}$$

$$day_{num} = \text{If}(\text{Round}(hour_{per}),\ 24,\ day_1,\ day_1,\ day_1 - 1 \cdot d) \tag{1411}$$

Week day:

$$day_{per,1} = day_{num} + 6 \cdot d - 7 \cdot \text{Trunc}\left(\frac{day_{num} + 6 \cdot d}{7}\right) \tag{1412}$$

(+6 in order to start on Sunday)

$$day_{per} = \text{If}\big(\text{Round}\big(day_{per,1}\big),\ 0,\ 7,\ 7,\ day_{per,1}\big) \tag{1413}$$

Week:

$$week_1 = \text{Trunc}\left(\frac{day_{num} + 6 \cdot d}{day/week}\right) + 1 \cdot w \tag{1414}$$

(+6 in order to start on Sunday)

$$week = \text{If}\big(\text{Round}\big(day_{per}\big),\ 7,\ week_1,\ week_1,\ week_1 - 1 \cdot w\big) \tag{1415}$$

(with each week starting on Sunday)

---

12. THERMAL COMFORT:

$$PPD_{cold,01} = -105.601073 + 55.5639137 \cdot t_{a,in,01} - 4.61379968 \cdot t_{a,in,01}^2 + 0.105768363 \cdot t_{a,in,01}^3 \tag{1416}$$

$$PPD_{hot,01} = 9625.81829 - 1026.04593 \cdot t_{a,in,01} + 36.0252538 \cdot t_{a,in,01}^2 - 0.414942196 \cdot t_{a,in,01}^3 \quad (1417)$$

$$PPD_{01} = \textbf{If}(t_{a,in,01},\ 21,\ PPD_{cold,01},\ PPD_{cold,01},\ \textbf{If}(t_{a,in,01},\ 25,\ 5,\ 5,\ PPD_{hot,01})) \quad (1418)$$

$$PPDnocc_{01} = PPD_{01} \cdot n_{occ,01} \quad (1419)$$

$$PPD_{average,01} = \frac{\int_{\tau_1}^{\tau_2} PPDnocc_{01}\, \mathbf{d}\tau}{\max\left(1,\ \left(\int_{\tau_1}^{\tau_2} n_{occ,01}\, \mathbf{d}\tau\right)\right)} \quad (1420)$$

$$PPD_{cold,02} = -105.601073 + 55.5639137 \cdot t_{a,in,02} - 4.61379968 \cdot t_{a,in,02}^2 + 0.105768363 \cdot t_{a,in,02}^3 \quad (1421)$$

$$PPD_{hot,02} = 9625.81829 - 1026.04593 \cdot t_{a,in,02} + 36.0252538 \cdot t_{a,in,02}^2 - 0.414942196 \cdot t_{a,in,02}^3 \quad (1422)$$

$$PPD_{02} = \textbf{If}(t_{a,in,02},\ 21,\ PPD_{cold,02},\ PPD_{cold,02},\ \textbf{If}(t_{a,in,02},\ 25,\ 5,\ 5,\ PPD_{hot,02})) \quad (1423)$$

$$PPDnocc_{02} = PPD_{02} \cdot n_{occ,02} \quad (1424)$$

$$PPD_{average,02} = \frac{\int_{\tau_1}^{\tau_2} PPDnocc_{02}\, \mathbf{d}\tau}{\max\left(1,\ \left(\int_{\tau_1}^{\tau_2} n_{occ,02}\, \mathbf{d}\tau\right)\right)} \quad (1425)$$

$$PPD_{cold,03} = -105.601073 + 55.5639137 \cdot t_{a,in,03} - 4.61379968 \cdot t_{a,in,03}^2 + 0.105768363 \cdot t_{a,in,03}^3 \quad (1426)$$

$$PPD_{hot,03} = 9625.81829 - 1026.04593 \cdot t_{a,in,03} + 36.0252538 \cdot t_{a,in,03}^2 - 0.414942196 \cdot t_{a,in,03}^3 \quad (1427)$$

$$PPD_{03} = \textbf{If}(t_{a,in,03},\ 21,\ PPD_{cold,03},\ PPD_{cold,03},\ \textbf{If}(t_{a,in,03},\ 25,\ 5,\ 5,\ PPD_{hot,03})) \quad (1428)$$

$$PPDnocc_{03} = PPD_{03} \cdot n_{occ,03} \quad (1429)$$

$$PPD_{average,03} = \frac{\int_{\tau_1}^{\tau_2} PPDnocc_{03}\, \mathbf{d}\tau}{\max\left(1,\ \left(\int_{\tau_1}^{\tau_2} n_{occ,03}\, \mathbf{d}\tau\right)\right)} \quad (1430)$$

$$PPD_{cold,04} = -105.601073 + 55.5639137 \cdot t_{a,in,04} - 4.61379968 \cdot t_{a,in,04}^2 + 0.105768363 \cdot t_{a,in,04}^3 \quad (1431)$$

$$PPD_{hot,04} = 9625.81829 - 1026.04593 \cdot t_{a,in,04} + 36.0252538 \cdot t_{a,in,04}^2 - 0.414942196 \cdot t_{a,in,04}^3 \quad (1432)$$

$$PPD_{04} = \textbf{If}(t_{a,in,04},\ 21,\ PPD_{cold,04},\ PPD_{cold,04},\ \textbf{If}(t_{a,in,04},\ 25,\ 5,\ 5,\ PPD_{hot,04})) \quad (1433)$$

$$PPDnocc_{04} = PPD_{04} \cdot n_{occ,04} \quad (1434)$$

$$PPD_{average,04} = \frac{\int_{\tau_1}^{\tau_2} PPDnocc_{04}\, \mathbf{d}\tau}{\max\left(1,\ \left(\int_{\tau_1}^{\tau_2} n_{occ,04}\, \mathbf{d}\tau\right)\right)} \quad (1435)$$

$$PPD_{cold,05} = -105.601073 + 55.5639137 \cdot t_{a,in,05} - 4.61379968 \cdot t_{a,in,05}^2 + 0.105768363 \cdot t_{a,in,05}^3 \quad (1436)$$

$$PPD_{hot,05} = 9625.81829 - 1026.04593 \cdot t_{a,in,05} + 36.0252538 \cdot t_{a,in,05}^2 - 0.414942196 \cdot t_{a,in,05}^3 \quad (1437)$$

$$PPD_{05} = \textbf{If}(t_{a,in,05},\ 21,\ PPD_{cold,05},\ PPD_{cold,05},\ \textbf{If}(t_{a,in,05},\ 25,\ 5,\ 5,\ PPD_{hot,05})) \quad (1438)$$

$$PPDnocc_{05} = PPD_{05} \cdot n_{occ,05} \quad (1439)$$

$$PPD_{average,05} = \frac{\int_{\tau_1}^{\tau_2} PPDnocc_{05}\, \mathbf{d}\tau}{\max\left(1,\ \left(\int_{\tau_1}^{\tau_2} n_{occ,05}\, \mathbf{d}\tau\right)\right)} \quad (1440)$$

```
$IntegralTable tau:3600, tau_winter, t_out, omega_out, f_occ, t_a_in_01, t_a_in_02,t_a_in_03,
```

$t_{out,mean}$=integral(t_{out},τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,01,mean}$=integral($t_{a,in,01}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,02,mean}$=integral($t_{a,in,02}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,03,mean}$=integral($t_{a,in,03}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,04,mean}$=integral($t_{a,in,04}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,05,mean}$=integral($t_{a,in,05}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)
$t_{a,in,06,mean}$=integral($t_{a,in,06}$,τ,τ_1,τ_2, $\Delta\tau$)/(τ_2-τ_1)

,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,

Building geometry and basic data JL130829-01

Variables in Main

Variables in Main

$$A_1 = 207 \ \left[\mathrm{m}^2\right] \qquad M_{dot,w,TUheatingcoil,01}, Q_{dot,TUheatingcoil,01}, hour_{per}, day_{num}, day_{per}, Q_{dot,sun}, Q_{dot,s,occ} \tag{1441}$$

A_{12345}=1662 [m^2]

$$A_{1,2} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1442}$$

$$A_{1,4} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1443}$$

$$A_{1,5} = 111.5 \ \left[\mathrm{m}^2\right] \tag{1444}$$

$$A_{1,6} = 208.4 \ \left[\mathrm{m}^2\right] \tag{1445}$$

$$A_{1,8} = 208.4 \ \left[\mathrm{m}^2\right] \tag{1446}$$

$$A_{1,9} = 151 \ \left[\mathrm{m}^2\right] \tag{1447}$$

$$A_{1,9,window} = 65 \ \left[\mathrm{m}^2\right] \tag{1448}$$

$$A_{1,9,opaque} = A_{1,9} - A_{1,9,window} \tag{1449}$$

$$A_2 = 131 \ \left[\mathrm{m}^2\right] \tag{1450}$$

$$A_{2,1} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1451}$$

$$A_{2,3} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1452}$$

$$A_{2,5} = 66.03 \ \left[\mathrm{m}^2\right] \tag{1453}$$

$$A_{2,6} = 132 \ \left[\mathrm{m}^2\right] \tag{1454}$$

$$A_{2,8} = 132 \ \left[\mathrm{m}^2\right] \tag{1455}$$

$$A_{2,9} = 101 \ \left[\mathrm{m}^2\right] \tag{1456}$$

$$A_{2,9,window} = 44 \ \left[\mathrm{m}^2\right] \tag{1457}$$

$$A_{2,9,opaque} = A_{2,9} - A_{2,9,window} \tag{1458}$$

$$A_3 = A_1 \tag{1459}$$

$$A_{3,2} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1460}$$

$$A_{3,4} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1461}$$

$$A_{3,5} = 111.5 \ \left[\mathrm{m}^2\right] \tag{1462}$$

$$A_{3,6} = 208.4 \ \left[\mathrm{m}^2\right] \tag{1463}$$

$$A_{3,8} = 208.4 \ \left[\mathrm{m}^2\right] \tag{1464}$$

$$A_{3,9} = A_{1,9} \tag{1465}$$

$$A_{3,9,opaque} = A_{1,9,opaque} \tag{1466}$$

$$A_{3,9,window} = A_{1,9,window} \tag{1467}$$

$$A_4 = A_2 \tag{1468}$$

$$A_{4,1} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1469}$$

$$A_{4,3} = 17.82 \ \left[\mathrm{m}^2\right] \tag{1470}$$

$$A_{4,5} = 66.03 \ \left[\mathrm{m}^2\right] \tag{1471}$$

$$A_{4,6} = 132 \ \left[\mathrm{m}^2\right] \tag{1472}$$

$$A_{4,8} = 132 \ \left[\mathrm{m}^2\right] \tag{1473}$$

$$A_{4,9} = 100.6 \ \left[\mathrm{m}^2\right] \tag{1474}$$

$$A_{4,9,opaque} = A_{2,9,opaque} \tag{1475}$$

$$A_{4,9,window} = A_{2,9,window} \tag{1476}$$

$$A_5 = 984 \ \left[\mathrm{m}^2\right] \tag{1477}$$

$$A_{5,1} = 111.5 \ \left[\mathrm{m}^2\right] \tag{1478}$$

$$A_{5,2} = 66.03 \ \left[\mathrm{m}^2\right] \tag{1479}$$

$$A_{5,3} = 111.5 \ \left[\mathrm{m}^2\right] \tag{1480}$$

$$A_{5,4} = 66.03 \ \left[\mathrm{m}^2\right] \tag{1481}$$

$$A_{5,6} = 984 \ \left[\mathrm{m}^2\right] \tag{1482}$$

$$A_{5,8} = 984 \ \left[\mathrm{m}^2\right] \tag{1483}$$

$$A_6 = A_1 + A_2 + A_3 + A_4 + A_5 \tag{1484}$$

$$A_{6,9} = 156 \ \left[\mathrm{m}^2\right] \tag{1485}$$

$$A_{6,9,opaque} = 156 \ \left[\mathrm{m}^2\right] \tag{1486}$$

$$A_{6,9,window} = 0 \ \left[\mathrm{m}^2\right] \tag{1487}$$

$$e_{floor} = 0.28 \ [\mathrm{m}] \tag{1488}$$

$$H1 = 2.74 \ [\mathrm{m}] \tag{1489}$$

$$H2 = 0.94 \ [\mathrm{m}] \tag{1490}$$

$$H3 = 1.3 \ [\mathrm{m}] \tag{1491}$$

$$L1 = 49.9 \ [\mathrm{m}] \quad (1492)$$

$$L2 = 33.3 \ [\mathrm{m}] \quad (1493)$$

$$L3 = 4.6 \ [\mathrm{m}] \quad (1494)$$

$$L4 = 24.1 \ [\mathrm{m}] \quad (1495)$$

$$V_1 = 569 \ \left[\mathrm{m}^3\right] \quad (1496)$$

V_{123456}=6115 [m^3]

$$V_2 = 360 \ \left[\mathrm{m}^3\right] \quad (1497)$$

$$V_3 = 569 \ \left[\mathrm{m}^3\right] \quad (1498)$$

$$V_4 = 360 \ \left[\mathrm{m}^3\right] \quad (1499)$$

$$V_5 = 2695 \ \left[\mathrm{m}^3\right] \quad (1500)$$

$$V_6 = 2025 \ \left[\mathrm{m}^3\right] \quad (1501)$$

Wall characteristics JL130914-01:

$$C/A_{floor} = 485760 \ \left[\mathrm{J/m^2{\cdot}C}\right] \quad (1502)$$

$$f_{\theta,floor} = 0.88 \quad (1503)$$

$$f_{\phi,floor} = 0.41 \quad (1504)$$

$$C/A_{wall,out} = 480543 \ \left[\mathrm{J/m^2{\cdot}K}\right] \quad (1505)$$

$$f_{\theta,wall} = 0.41 \quad (1506)$$

$$f_{\phi,wall} = 0.31 \quad (1507)$$

$$c_{concrete} = 880 \ [\mathrm{J/kg{\cdot}C}] \quad (1508)$$

$$c_{gypsum} = 1085 \ [\mathrm{J/kg{\cdot}K}] \quad (1509)$$

$$c_{stucco} = 1085 \ [\mathrm{J/kg{\cdot}K}] \quad (1510)$$

$$e_{concrete,floor} = 0.24 \ [\mathrm{m}] \quad (1511)$$

$$e_{concrete,wall,out} = 0.2032 \ [\mathrm{m}] \quad (1512)$$

$$e_{gypsum} = 0.0127 \ [\mathrm{m}] \quad (1513)$$

$$e_{stucco} = 0.0253 \ [\mathrm{m}] \quad (1514)$$

$$h_{in} = 8 \ \left[\mathrm{W/m^2{\cdot}C}\right] \quad (1515)$$

$$h_{out} = 23 \ \left[\mathrm{W/m^2{\cdot}C}\right] \quad (1516)$$

$$\rho_{concrete} = 2300 \ \left[\mathrm{kg/m^3}\right] \quad (1517)$$

$$\rho_{gypsum} = 1680 \ \left[\mathrm{kg/m^3}\right] \quad (1518)$$

$$\rho_{stucco} = 1680 \ \left[\mathrm{kg/m^3}\right] \quad (1519)$$

S_{window}=0.52 [-]

$$S_{window} = 0.26 \ [\text{-}] \tag{1520}$$

$$U_{ceiling} = 1.36 \ \left[\text{W/m}^2\text{·K}\right] \tag{1521}$$

$$U_{floor} = 1 \ \left[\text{W/m}^2\text{·K}\right] \tag{1522}$$

$$U_{partition} = 3 \ \left[\text{W/m}^2\text{·K}\right] \tag{1523}$$

$$U_{wall,out} = 0.69 \ \left[\text{W/m}^2\text{·K}\right] \tag{1524}$$

$$U_{window} = 1.6 \ \left[\text{W/m}^2\text{·K}\right] \tag{1525}$$

Plot Window 1: *Plot* 1