
Simulink Report: Mixing_Unit_4D_

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Model - Mixing_Unit_4D_

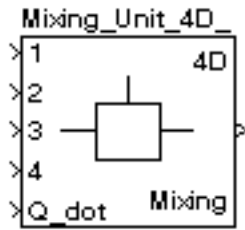


Tabelle 1.1. Mixing_Unit_4D_ Simulation Parameters

<i>Solver</i> ode14x	<i>ZeroCross</i> on	<i>StartTime</i> 0.0 <i>StopTime</i> 10.0
<i>RelTol</i> 1e-3	<i>AbsTol</i> auto	<i>Refine</i> 1
<i>InitialStep</i> auto	<i>FixedStep</i> auto	<i>MaxStep</i> auto

Tabelle 1.2. Mixing_Unit_4D_ Summary Information

<i>NumModelInputs</i>	N/A	<i>NumModelOutputs</i>	N/A
<i>NumVirtualSubsystems</i>	N/A	<i>NumNonvirtSubsystems</i>	N/A
<i>NumNonVirtBlocksInModel</i>	N/A	<i>NumBlockTypeCounts</i>	N/A
<i>NumBlockSignals</i>	N/A	<i>NumBlockParams</i>	N/A
<i>NumZCEvents</i>	N/A	<i>NumNonsampledZCs</i>	N/A

Systems

Name	Parent	Snapshot	Blocks	Signals
Mixing_Unit_4D_	<root>		Mixing_Unit_4D_	Mixing_Unit_4D_<1>

Blocks

Tabelle 1.3. Block Type Count



BlockType	Count	Block Names
Inport	46	In_1, In_2, In_3, In_4, Q_dot, V, p_init, T_init, x_H2O_gas_init, x_CO2_init, x_H2O_liq_init, T, m_air, m_H2O_gas, m_CO2, m_H2O_liq, T_in_1, m_dot_air_in_1, x_H2O_gas_in_1, x_CO2_in_1, x_H2O_liq_in_1, T_in_2, m_dot_air_in_2, x_H2O_gas_in_2, x_CO2_in_2, x_H2O_liq_in_2,

BlockType	Count	Block Names
		, m_dot_air_in_3, x_H2O_gas_in_3, x_CO2_in_3, x_H2O_liq_in_3, T_in_4, m_dot_air_in_4, x_H2O_gas_in_4, x_CO2_in_4, x_H2O_liq_in_4, Q_dot, T, m_air, m_H2O_gas, m_CO2, m_H2O_liq, V, Delta_T_old, Delta_m_H2O_gas_old, Delta_m_H2O_liq_old
Output	19	m_air_init, m_H2O_gas_init, m_CO2_init, m_H2O_liq_init, T_dot, m_dot_air, m_dot_H2O_gas, m_dot_CO2, m_dot_H2O_liq, p, rho_bar, T_bar, x_H2O_gas_bar, x_CO2, x_H2O_liq_bar, Delta_T, Delta_m_H2O_gas, Delta_m_H2O_liq, Out
Constant	7	T_init, V, m_dot_air, p_init, x_CO2_init, x_H2O_gas_init, x_H2O_liq_init
Integrator	5	Integrator1, Integrator2, Integrator3, Integrator4, Integrator5
BusSelector	4	Bus Selector1, Bus Selector2, Bus Selector3, Bus Selector5
UnitDelay	3	Unit Delay, Unit Delay1, Unit Delay2
Terminator	3	Terminator , Terminator , Terminator
Stateflow (m)	3	Embedded MATLAB Function, Embedded_MATLAB_Function_1, Embedded_MATLAB_Function_2
S-Function	3	SFunction , SFunction , SFunction
Demux	3	Demux , Demux , Demux
Product	2	Product, Product1
SubSystem	1	Mixing_Unit_4D_
BusCreator	1	Bus Creator2

Data and Functions

Tabelle 1.4. Model Functions

Function Name	Parent Blocks	Calling string
NaN	Mixing_Unit_4D_ Mixing_Unit_4D_ Mixing_Unit_4D_ Mixing_Unit_4D_ Mixing_Unit_4D_ Mixing_Unit_4D_	NaN NaN NaN NaN NaN NaN

 **Function Block Parameters: Mixing_Unit_4D_** 

Subsystem (mask)

Parameters

Volume [m³]

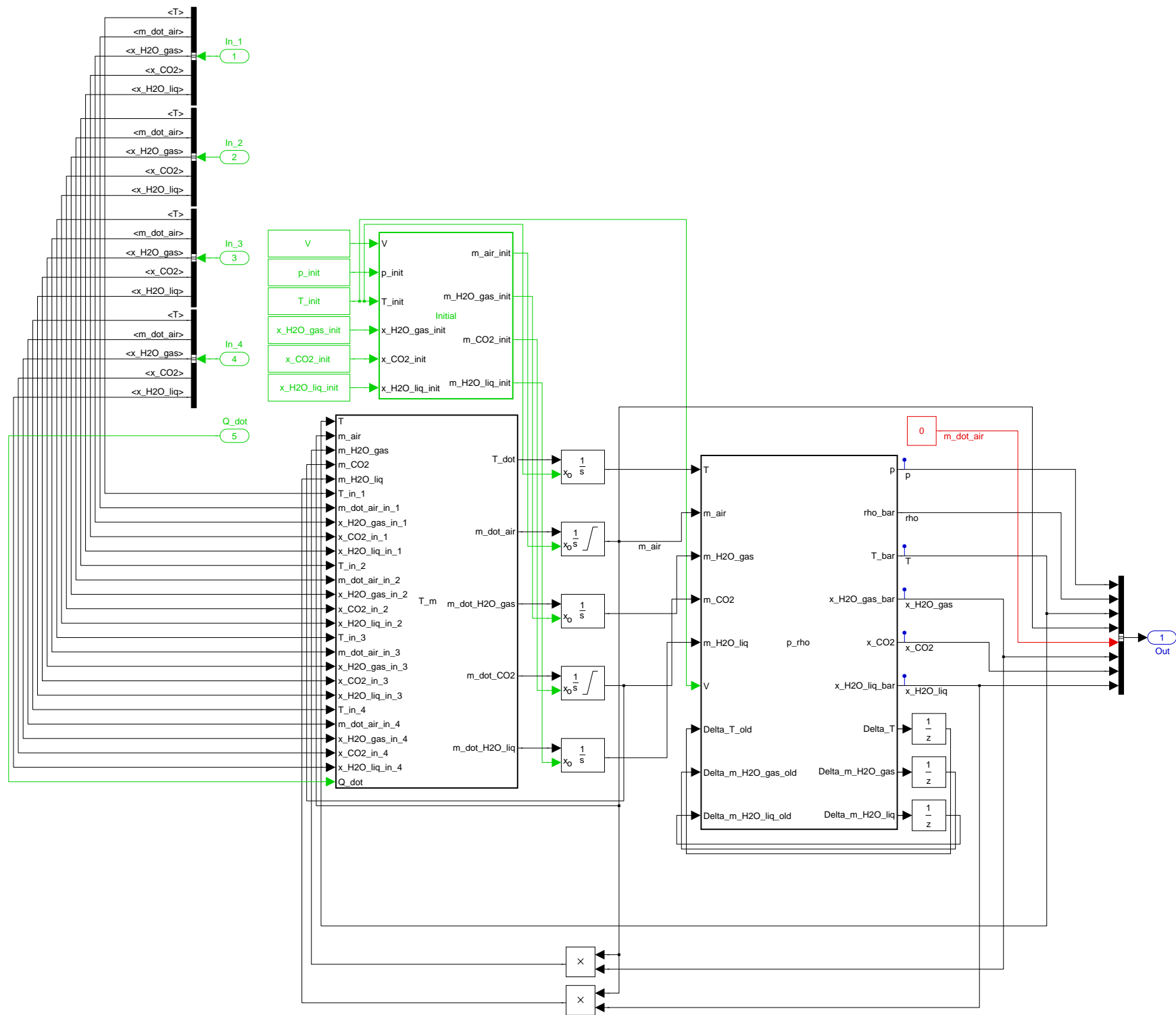
Initial Parameter: Pressure [Pa]

Initial Parameter: Temperature [K]

Initial Parameter: Water Vapor Content

Initial Parameter: CO2 Content

Initial Parameter: Water Content



```
function [m_air_init,m_H2O_gas_init,m_CO2_init,m_H2O_liq_init] = Initial(V,p_init,
T_init,x_H2O_gas_init,x_CO2_init,x_H2O_liq_init)
```

```
% *****
% * Definition of a mixing unit with 4 apertures
% *
% * Number of Inputs:          5
% *
% * Parameter : Volume:       V
% *
% *
% * Relevant input variables of Mixing_Unit_4D:
% *
% * Temperature:              T
% * Mass flow dry air:        m_dot_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% * External Heat Flow:      Q_dot
% *
% *
% * Relevant output variables of Mixing_Unit_4D:
% *
% * Pressure:                  p
% * Density:                   rho
% * Temperature:              T
% * Mass dry air:              m_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% *
% *****
% * Embedded MATLAB Function Initial:
% *
% * Calculations:
% * 1. Definition specific gas constants.
% * 2. Calculation of the saturation density by a given temperature.
% * 3. Calculation of the saturation mass.
% * 4. Initialisation.
% *
% *
% *
% * Assumptions:
% * 1. The gas mixture inside the volume consists of water vapor (H2O_gas),
% *    CO2 and water (H2O_liq, state: fog).
% * 2. The saturation density is a function of the temperature. The used
% *    function is described in literature.
% *
% *
% * Last modification : 15.03.2008
% * Author : Christian Müller(HAW)
% *
% *****

% * 1. Definition specific gas constants
R_air          = 287.058;
```

```

R_H2O_gas      = 461.523;
R_CO2          = 188.924;
% *****

% * 2. Calculation of the saturation density by a given temperature
rho_H2O_gas_sat = 4.44259*exp(15.05703*(T_init-273.15)/(208.07254+(T_init-273.15)))
/1000;
% *****

% * 3. Calculation of the saturation mass
m_H2O_gas_sat   = V*rho_H2O_gas_sat;
% *****

% * 4. Initialisation
m_air_init      = p_init*V/(T_init*
(R_air+x_H2O_gas_init*R_H2O_gas+x_CO2_init*R_CO2));
m_H2O_gas_init  = m_air_init*x_H2O_gas_init;

if m_H2O_gas_init > m_H2O_gas_sat
    m_H2O_gas_init = m_H2O_gas_sat;
    m_air_init     = ((p_init*V/T_init)-(m_H2O_gas_init*R_H2O_gas))/
(R_air+x_CO2_init*R_CO2);
end

m_CO2_init      = m_air_init*x_CO2_init;
m_H2O_liq_init  = m_air_init*x_H2O_liq_init;
% *****

```

```

function [T_dot,m_dot_air,m_dot_H2O_gas,m_dot_CO2,m_dot_H2O_liq] = T_m(T,m_air,↵
m_H2O_gas,m_CO2,m_H2O_liq,T_in_1,m_dot_air_in_1,x_H2O_gas_in_1,x_CO2_in_1,↵
x_H2O_liq_in_1,T_in_2,m_dot_air_in_2,x_H2O_gas_in_2,x_CO2_in_2,x_H2O_liq_in_2,T_in_3,↵
m_dot_air_in_3,x_H2O_gas_in_3,x_CO2_in_3,x_H2O_liq_in_3,T_in_4,m_dot_air_in_4,↵
x_H2O_gas_in_4,x_CO2_in_4,x_H2O_liq_in_4,Q_dot)

% *****
% * Definition of a mixing unit with 4 apertures
% *
% * Number of Inputs:          5
% *
% * Parameter : Volume:       V
% *
% *
% * Relevant input variables of Mixing_Unit_4D:
% *
% * Temperature:              T
% * Mass flow dry air:        m_dot_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% * External Heat Flow:      Q_dot
% *
% *
% * Relevant output variables of Mixing_Unit_4D:
% *
% * Pressure:                  p
% * Density:                   rho
% * Temperature:              T
% * Mass dry air:              m_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% *
% *****
% * Embedded MATLAB Function T_m:
% *
% * Calculations:
% * 1. Definition specific gas constants.
% * 2. Modification of the mass inside the system.
% * 3. Redefinition of the input variables.
% * 4. Modification of the temperature inside the system.
% *
% *
% * Assumptions:
% * 1. The gas mixture inside the volume consists of water vapor (H2O_gas),
% *    CO2 and water (H2O_liq, state: fog).
% * 2. The increase or decrease of the mass inside the volume is defined
% *    by the incoming (sign: plus) or outgoing (sign: minus) mass flow.
% * 3. In the case of outgoing mass flow, the characteristic variables of
% *    the mass flow are defined by the state variables of the volume.
% * 4. The Enthalpy equation of the gas inside the volume is used. the
% *    enthalpy of the liquid water inside the volume is neglected.
% *    Assuming that the liquid water is always in thermal equilibrium with
% *    the gas.
% *

```



```

% *
% * Last modification : 15.03.2008
% * Author : Christian Müller(HAW)
% *
% *****

% * 1. Definition specific gas constants
R_air      = 287.058;
R_H2O_gas  = 461.523;
R_CO2      = 188.924;
c_p_air    = 1005;
c_p_H2O_gas = 1870;
c_p_CO2    = 830;
c_v_air    = c_p_air-R_air;
c_v_H2O_gas = c_p_H2O_gas-R_H2O_gas;
c_v_CO2    = c_p_CO2-R_CO2;
% *****

% * 2. Redefinition of the input variables
if m_dot_air_in_1 < 0
    T_in_1      = T;
    m_dot       = m_dot_air_in_1*(1+x_H2O_gas_in_1+x_CO2_in_1);
    m_dot_air_in_1 = m_dot*(1/(1+(m_H2O_gas/m_air)+(m_CO2/m_air)));
    x_H2O_gas_in_1 = (m_H2O_gas/m_air);
    x_CO2_in_1    = (m_CO2/m_air);
    x_H2O_liq_in_1 = (m_H2O_liq/m_air);
end

if m_dot_air_in_2 < 0
    T_in_2      = T;
    m_dot       = m_dot_air_in_2*(1+x_H2O_gas_in_2+x_CO2_in_2);
    m_dot_air_in_2 = m_dot*(1/(1+(m_H2O_gas/m_air)+(m_CO2/m_air)));
    x_H2O_gas_in_2 = (m_H2O_gas/m_air);
    x_CO2_in_2    = (m_CO2/m_air);
    x_H2O_liq_in_2 = (m_H2O_liq/m_air);
end

if m_dot_air_in_3 < 0
    T_in_3      = T;
    m_dot       = m_dot_air_in_3*(1+x_H2O_gas_in_3+x_CO2_in_3);
    m_dot_air_in_3 = m_dot*(1/(1+(m_H2O_gas/m_air)+(m_CO2/m_air)));
    x_H2O_gas_in_3 = (m_H2O_gas/m_air);
    x_CO2_in_3    = (m_CO2/m_air);
    x_H2O_liq_in_3 = (m_H2O_liq/m_air);
end

if m_dot_air_in_4 < 0
    T_in_4      = T;
    m_dot       = m_dot_air_in_4*(1+x_H2O_gas_in_4+x_CO2_in_4);
    m_dot_air_in_4 = m_dot*(1/(1+(m_H2O_gas/m_air)+(m_CO2/m_air)));
    x_H2O_gas_in_4 = (m_H2O_gas/m_air);
    x_CO2_in_4    = (m_CO2/m_air);
    x_H2O_liq_in_4 = (m_H2O_liq/m_air);
end
% *****

```

```

% * 3. Modification of the mass inside the system
m_dot_air          = m_dot_air_in_1+m_dot_air_in_2+m_dot_air_in_3+m_dot_air_in_4;
m_dot_H2O_gas       = ✓
m_dot_air_in_1*x_H2O_gas_in_1+m_dot_air_in_2*x_H2O_gas_in_2+m_dot_air_in_3*x_H2O_gas_in_3+m_dot_air_in_4*x_H2O_gas_in_4;
m_dot_CO2           = ✓
m_dot_air_in_1*x_CO2_in_1+m_dot_air_in_2*x_CO2_in_2+m_dot_air_in_3*x_CO2_in_3+m_dot_air_in_4*x_CO2_in_4;
m_dot_H2O_liq       = ✓
m_dot_air_in_1*x_H2O_liq_in_1+m_dot_air_in_2*x_H2O_liq_in_2+m_dot_air_in_3*x_H2O_liq_in_3+m_dot_air_in_4*x_H2O_liq_in_4;
% *****

% * 4. Modification of the temperature inside the system
T_dot              = (Q_dot+m_dot_air_in_1*(c_p_air*T_in_1-c_v_air*T)+m_dot_air_in_2*(c_p_air*T_in_2-c_v_air*T)+m_dot_air_in_3*(c_p_air*T_in_3-c_v_air*T)+m_dot_air_in_4*(c_p_air*T_in_4-c_v_air*T)+m_dot_air_in_1*x_H2O_gas_in_1*(c_p_H2O_gas*T_in_1-c_v_H2O_gas*T)+m_dot_air_in_2*x_H2O_gas_in_2*(c_p_H2O_gas*T_in_2-c_v_H2O_gas*T)+m_dot_air_in_3*x_H2O_gas_in_3*(c_p_H2O_gas*T_in_3-c_v_H2O_gas*T)+m_dot_air_in_4*x_H2O_gas_in_4*(c_p_H2O_gas*T_in_4-c_v_H2O_gas*T)+m_dot_air_in_1*x_CO2_in_1*(c_p_CO2*T_in_1-c_v_CO2*T)+m_dot_air_in_2*x_CO2_in_2*(c_p_CO2*T_in_2-c_v_CO2*T)+m_dot_air_in_3*x_CO2_in_3*(c_p_CO2*T_in_3-c_v_CO2*T)+m_dot_air_in_4*x_CO2_in_4*(c_p_CO2*T_in_4-c_v_CO2*T))/(c_v_air*m_air+c_v_H2O_gas*m_H2O_gas+c_v_CO2*m_CO2);
% *****

```

```
function [p,rho_bar,T_bar,x_H2O_gas_bar,x_CO2,x_H2O_liq_bar,Delta_T,Delta_m_H2O_gas,↵
Delta_m_H2O_liq] = p_rho(T,m_air,m_H2O_gas,m_CO2,m_H2O_liq,V,Delta_T_old,↵
Delta_m_H2O_gas_old,Delta_m_H2O_liq_old)
```

```
% *****
% * Definition of a mixing unit with 4 aperture
% *
% * Number of Inputs:          5
% *
% * Parameter : Volume:       V
% *
% *
% * Relevant input variables of Mixing_Unit_4D:
% *
% * Temperature:              T
% * Mass flow dry air:        m_dot_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% * External Heat Flow:      Q_dot
% *
% *
% * Relevant output variables of Mixing_Unit_4D:
% *
% * Pressure:                  p
% * Density:                   rho
% * Temperature:              T
% * Mass dry air:              m_air
% * Content water vapor:      x_H2O_gas
% * Content CO2:              x_CO2
% * Content water:            x_H2O_liq
% *
% *****
% * Embedded MATLAB Function p_rho:
% *
% * Calculations:
% * 1. Redefinition of the input variables.
% * 2. Definition specific gas constants.
% * 3. Calculation of the density.
% * 4. Calculation of the pressure.
% * 5. Calculation of the water vapor content, CO2 content and
% *    water content.
% * 6. Condensation/Evaporation
% *
% *
% * Assumptions:
% * 1. The gas mixture inside the volume consists of water vapor (H2O_gas),
% *    CO2 and water (H2O_liq, state: fog).
% * 5. The differnt contents are defined in respect of the mass of the
% *    dry air.
% *
% *
% * Last modification : 15.03.2008
% * Author : Christian Müller(HAW)
% *
% *****
```

```

% * 1. Redefinition of the input variables
T                = T+Delta_T_old;

if T < 0
    T            = 0;
end

m_H2O_gas        = m_H2O_gas+Delta_m_H2O_gas_old;

if m_H2O_gas < 0
    m_H2O_gas    = 0;
end

m_H2O_liq        = m_H2O_liq+Delta_m_H2O_liq_old;

if m_H2O_liq < 0
    m_H2O_liq    = 0;
end
% *****

% * 2. Definition specific gas constants
R_air            = 287.058;
R_H2O_gas        = 461.523;
R_CO2            = 188.924;
c_p_air          = 1005;
c_p_H2O_gas      = 1870;
c_p_CO2          = 830;
c_p_H2O_liq      = 4173;
c_p_H2O_ice      = 2050;
r_0              = 2500000;
r_ice            = 333000;
% *****

% * 3. Calculation of the density
rho              = (m_air+m_H2O_gas+m_CO2)/V;
% *****

% * 4. Calculation of the pressure
p                = T*(m_air*R_air+m_H2O_gas*R_H2O_gas+m_CO2*R_CO2)/V;
% *****

% * 5. Calculation of the water vapor content, CO2 content and
% *      water content
x_H2O_gas        = m_H2O_gas/m_air;
x_CO2            = m_CO2/m_air;
x_H2O_liq        = m_H2O_liq/m_air;
% *****

% * 6. Condensation/Evaporation
rho_bar          = rho;
T_bar            = T;
x_H2O_gas_bar    = x_H2O_gas;
x_H2O_liq_bar    = x_H2O_liq;
rho_H2O_gas_sat  = 4.44259*exp(15.05703*(T-273.15)/(208.07254+(T-273.15)))

```

```

/1000;
x_H2O_gas_sat      = rho_H2O_gas_sat/(m_air/V);
evap                = 0;
cond                = 0;

if x_H2O_gas_sat > x_H2O_gas
    evap            = 1;
end

if x_H2O_gas_sat < x_H2O_gas
    cond            = 1;
end

if evap>0
    test            = 1;
    iter            = 0;

    while test>0
        rho_H2O_gas_sat_evap = 4.44259*exp(15.05703*(T_bar-273.15)/(208.07254+(T_bar-
273.15)))/1000;
        x_H2O_gas_sat_evap   = rho_H2O_gas_sat_evap/(m_air/V);

        if (x_H2O_gas_sat_evap-x_H2O_gas)<x_H2O_liq
            x_H2O_gas_bar     = x_H2O_gas_sat_evap;
        else
            x_H2O_gas_bar     = x_H2O_gas+x_H2O_liq;
        end

        h_air_T              = (c_p_air+x_H2O_gas*c_p_H2O_gas+x_CO2*c_p_CO2)*T;
        h_H2O_liq_T          = x_H2O_liq*c_p_H2O_liq*T;
        Q_lat                 = r_0*(x_H2O_gas_bar-x_H2O_gas);
        Z_T_bar               = (h_air_T+h_H2O_liq_T-Q_lat)/
(c_p_air+x_H2O_gas_bar*c_p_H2O_gas+x_CO2*c_p_CO2+(x_H2O_liq-(x_H2O_gas_bar-x_H2O_gas))
*c_p_H2O_liq);

        if T < 273.15
            h_H2O_ice_T       = x_H2O_liq*c_p_H2O_ice*T+(x_H2O_gas_bar-x_H2O_gas)
*r_ice;
            Z_T_bar           = (h_air_T+h_H2O_ice_T-Q_lat)/
(c_p_air+x_H2O_gas_bar*c_p_H2O_gas+x_CO2*c_p_CO2+(x_H2O_liq-(x_H2O_gas_bar-x_H2O_gas))
*c_p_H2O_ice);
        end

        Z_T_bar               = (Z_T_bar+T_bar)/2;

        if abs(Z_T_bar-T_bar) < 0.1
            test               = 0;
        end

        if iter > 10
            test               = 0;
        end

        T_bar                 = Z_T_bar;
        iter                  = iter+1;
    end
end

```

```

if T_bar >= T
    T_bar          = T;
    rho_bar        = rho;
    x_H2O_gas_bar   = x_H2O_gas;
    x_H2O_liq_bar   = x_H2O_liq;
else
    x_H2O_liq_bar   = x_H2O_liq-(x_H2O_gas_bar-x_H2O_gas);
    R_avg           = (R_air+x_H2O_gas_bar*R_H2O_gas+x_CO2*R_CO2)/
(1+x_H2O_gas_bar+x_CO2);
    rho_bar         = p/(R_avg*T_bar);
end
end

if cond>0
    test           = 1;
    iter           = 0;
    x_H2O_gas_sat_cond = 0;

    while test > 0
        rho_H2O_gas_sat_cond = 4.44259*exp(15.05703*(T_bar-273.15)/(208.07254+(T_bar-
273.15)))/1000;
        x_H2O_gas_sat_cond   = rho_H2O_gas_sat_cond/(m_air/V);
        h_air_T              = (c_p_air+x_H2O_gas*c_p_H2O_gas+x_CO2*c_p_CO2)*T;
        h_H2O_liq_T          = x_H2O_liq*c_p_H2O_liq*T;
        Q_lat                 = r_0*(x_H2O_gas-x_H2O_gas_sat_cond);
        Z_T_bar               = (h_air_T+h_H2O_liq_T+Q_lat)/
(c_p_air+x_H2O_gas_sat_cond*c_p_H2O_gas+x_CO2*c_p_CO2+(x_H2O_liq+(x_H2O_gas-
x_H2O_gas_sat_cond))*c_p_H2O_liq);

        if T < 273.15
            h_H2O_ice_T       = x_H2O_liq*c_p_H2O_ice*T-(x_H2O_gas-x_H2O_gas_sat_cond)*r_ice;
            Z_T_bar           = (h_air_T+h_H2O_ice_T+Q_lat)/
(c_p_air+x_H2O_gas_sat_cond*c_p_H2O_gas+x_CO2*c_p_CO2+(x_H2O_liq+(x_H2O_gas-
x_H2O_gas_sat_cond))*c_p_H2O_ice);
        end

        Z_T_bar              = (Z_T_bar+T_bar)/2;

        if abs(Z_T_bar-T_bar) < 0.1
            test              = 0;
        end

        if iter > 10
            test              = 0;
        end

        T_bar                = Z_T_bar;
        iter                  = iter+1;
    end

    if T_bar <= T
        T_bar                = T;
        rho_bar               = rho;
        x_H2O_gas_bar         = x_H2O_gas;

```

```

        x_H2O_liq_bar      = x_H2O_liq;
    else
        x_H2O_gas_bar      = x_H2O_gas_sat_cond;
        x_H2O_liq_bar      = x_H2O_liq+(x_H2O_gas-x_H2O_gas_sat_cond);
        R_avg              = (R_air+x_H2O_gas_bar*R_H2O_gas+x_CO2*R_CO2)/
(1+x_H2O_gas_bar+x_CO2);
        rho_bar            = p/(R_avg*T_bar);
    end
end

Delta_T                  = Delta_T_old+T_bar-T;
Delta_m_H2O_gas          = Delta_m_H2O_gas_old+m_air*(x_H2O_gas_bar-x_H2O_gas);
Delta_m_H2O_liq          = Delta_m_H2O_liq_old+m_air*(x_H2O_liq_bar-x_H2O_liq);
% *****

```