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IAQ Certification Tool for Ventilation Systems

Modeling of the Systems

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Department of Climatology – Aerodynamics – Pollution – Purification

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1 PURPOSE

The work presented in this report aims to formalize the models used to represent systems in the MATHIS [1] [2] calculation code as part of the IAQ certification project of ventilation systems. We also present the way in which the user supplies these models with input data. This report aims to serve as a guide for using the system setup interface, for the tool's end user.

2 MODELED SYSTEMS

The tool can be used to represent mechanical ventilation systems of the following types:

- central, single flow (by air exhaust or air supply);
- central, double flow;
- single-room, single flow;
- single-room, double flow.

In order to be able to take account of the potential variability of the characteristics of the systems, as defined during the development of the tool, a generic modeling approach was adopted.

Thus, a ventilation system is defined by the description of the types of intake and exhaust (mechanical or natural) and for each one by:

- the presence or absence of a ductwork system in the case of mechanical modes (the absence of ductwork means that the system is decentralized, or per-room);
- if applicable, the type of ductwork system (individual or collective) and its characteristics (tightness class, type of duct impacting the roughness, the presence or absence of a plenum chamber, the diameter of the air intake or exhaust main duct, the diameters of the ducts leading to the terminal components for air intake or exhaust as well as those of the main ducts);
- the characteristics of the terminal components (flow/pressure law, control mode) and their positioning in the building under consideration;
- the characteristics of the ventilation units (flow/pressure law, consumption/flow law, control mode, characteristics of the heat exchanger) and their position in the building under consideration.

This report confines itself to presenting the component and ductwork models specifically used in the project.

To find out more about the MATHIS calculation code, consult the following references: [1] and [2]. The airflow model used by the MATHIS software is based on the principle of the breakdown of a building into nodes and branches. A node represents the volume of a room or of a portion of an airflow system, and branches represent the airflow connections between these volumes. The data concerning the conservation of mass and of the internal energy in the nodes provides access to the pressure and mass fractions of the chemical species of the corresponding volume. The data concerning the conservation of the mechanical energy in the branches provides access to the flowrates passing through them.

Excel has been chosen as an input interface of the ventilation system's characteristics, in order to facilitate exchanges between the end user of the tool and the industrial company seeking certification.

A setup file, "template.xls", downloadable through the tool, comprises various tabs (***system***, ***catalogue***, ***supply***, ***exhaust***, ***fan1***, ***fan2***, ***fan3***).

In each tab of this setup file, the light green boxes need to be filled in using a dropdown list. The gray boxes are filled in with a value defined by the user. Generally speaking, the data must be entered in the columns, in order from left to right, because certain dropdown lists depend on other ones. There are comments in various parts of the file to guide the user and provide reminders of certain rules described in this report. The reader is assumed to have this file.

The following chapters present the manner in which the input data is stipulated in these different tabs, and how this data is integrated into the physical modeling of the system operation.

3 NOMENCLATURE

RH	%	Relative humidity
k		Linear pressure loss coefficient
K_b		Empirical coefficient of the flow/pressure law of an air terminal
L	m	Duct length
$\tilde{P}$	Pa	Total ground pressure of a node
Qv	m^3/h	Volume flowrate
S	m^2	Section
T	°C	Temperature
z	m	Height of a node measured from ground
ρ	$kg.m^{-3}$	Density
ρ^*	$kg.m^{-3}$	Density of the gas passing through a component
ζ	-	Local pressure loss coefficient

4 DESCRIPTION OF THE TYPES AND MODES OF SUPPLY AND EXHAUST TERMINAL (*SYSTEM* TAB)

The ***system*** tab is primarily used for describing the types and modes of supply (***SUPPLY*** line) and exhaust (***EXHAUST*** line). In order to be modeled, a ventilation system must have a single supply mode and a single exhaust mode. A supply mode can be combined with a different exhaust mode.

This data is entered using conditional dropdown lists. Thus, natural supply or exhaust (***natural***) can only be combined with a decentralized per-room mode (***per_room***). Mechanical supply or exhaust (***mechanical***) can be combined with a centralized mode (***ductwork***) or with a per-room decentralized mode (***per_room***).

The tables below present a few examples of data entry for various systems.

Table 1: Central single flow exhaust mechanical ventilation system

	Type	Mode
SUPPLY	natural	per_room
EXHAUST	mechanical	ductwork

Table 2: Central single flow supply mechanical ventilation system

	Type	Mode
SUPPLY	mechanical	ductwork
EXHAUST	natural	per_room

Table 3: Central double flow mechanical ventilation system

	Type	Mode
SUPPLY	mechanical	ductwork
EXHAUST	mechanical	ductwork

Table 4: Single-room double flow mechanical ventilation system

	Type	Mode
SUPPLY	mechanical	per_room
EXHAUST	mechanical	per_room

5 DESCRIPTION OF THE DUCTWORK SYSTEM(S) (*SYSTEM* TAB)

Where appropriate, for example, if the centralized mode - ***ductwork*** - has been selected previously for the supply or exhaust, then next, in the ***system*** tab, the characteristics and diameters of the ducts of the associated ductwork system are described.

Table 5 and Table 6 below present an example of data entry for the main characteristics corresponding to the ductwork of an individual central single flow exhaust mechanical ventilation system. The first line corresponds to the supply, so it does not have any specific indication here. Paragraphs 5.1 to 5.6 below give details about how the values of each column are entered and their implications in the model.

Table 5: Example of data entry for the main characteristics of the ductwork in an individual single flow exhaust mechanical ventilation system

Ductwork Specifications				
Ductwork Type	**Tightness**	**Roughness**	**Zeta Plenum**	**In/out Diameter (m)**
___	___	___		
individual	**Class_A**	**flexible**	0.	0.160

Table 6: Example of data entry for the diameters of the secondary ducts in the ductwork of an individual single flow exhaust mechanical ventilation system

Ducts Diameters (m)						
hall	**Living**	**Bedroom**	**Kitchen**	**WC**	**Bathroom**	**Bathroom-WC**
			0.125	0.080	0.080	0.080

5.1 Type of ductwork (*Ductwork Type* column)

5.1.1 Settings

A dropdown list is used to select if the system is individual (***individual***, i.e. the system only applies to a single housing unit, whether it is a single family home or a housing unit in an apartment building or condominium) or collective (***collective***; this must be selected only if the system's scope of use, selected before the calculations were made, concerns collective housing and the system actually applies to several housing units simultaneously).

5.1.2 Individual ductwork system model

An individual ductwork system has been selected (Figure 1). It comprises:

– an air inlet (or outlet) with a local pressure loss coefficient ζ_{io};

- a supply (or exhaust) duct with a diameter D_{io};
- a main duct with the same diameter D_{io};
- a distribution plenum with a pressure loss coefficient ζ_p;
- secondary ducts with diameters D_{vi} where i represents secondary duct i.

We have chosen as a supply duct a straight rigid duct with a length of 1 m. This is based on the test code "*GS14.5 VMC simple flux hygroréglable – Code d'essais aérauliques et acoustiques (revision 04)*" for which the ventilation unit is connected to a rigid duct 3D-length.

At the beginning of the calculation, a random draw defines the total length L_{tot} of duct between the fan and the air terminals, as well as the number of bends N_c depending on the type of building. The user also indicates whether there is a distribution plenum or not (section 5.4).

When there is a plenum, we suggest that the main duct should be a straight rigid duct of a length equal to a quarter of the total length of the ductwork system.

The secondary ducts are flexible or rigid ducts as decided by the user, each presenting a number of bends equal to the number drawn randomly and with a length equal to the total length, but shorter than that of the main duct (if there is no plenum, the secondary ducts are thus the total length and are directly connected to the fan).

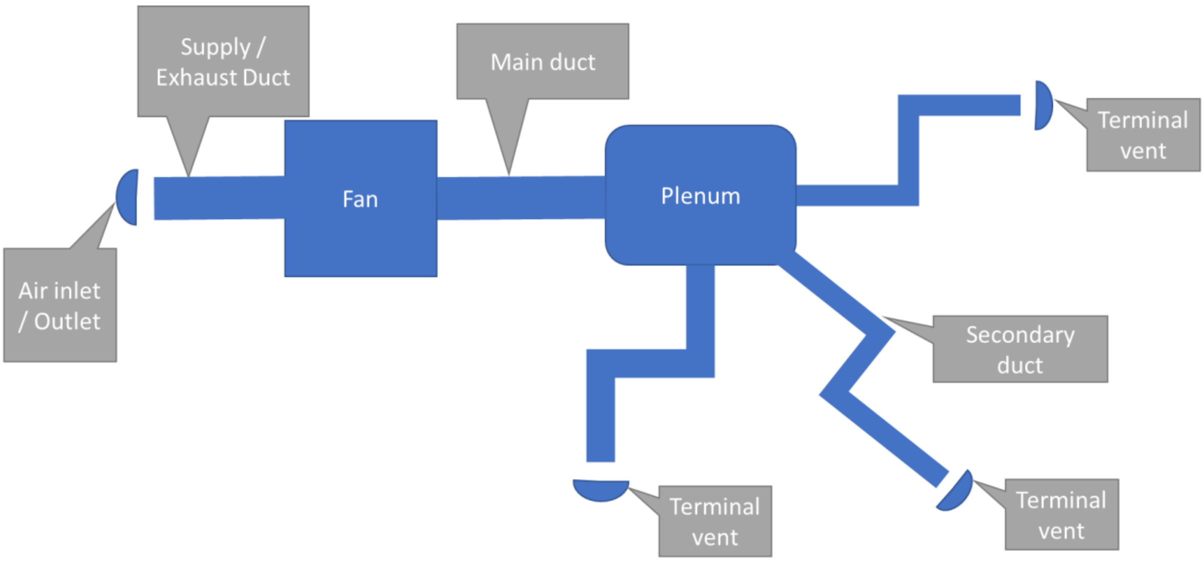

Figure 1: Diagram of the standard individual ductwork system model

Each air terminal experiences a different system pressure according to the length and air flow of its duct. This pressure is evaluated at each time step.

The linear pressure loss of each duct is calculated according to [3]. The local pressure loss of each duct is calculated based on local pressure loss coefficients defined for the bends, the plenum and the inlet (or outlet).

Thus, the pressure loss ΔP_i (Pa) of each duct is expressed as follows:

$$\Delta P_i = \left[\frac{k_{io}.L_{io}.\left(Q_{v,io}\right)^{1.9}}{(1000.D_{io})^5} + \left(\zeta_{io} + \zeta_p\right)\frac{\rho^* {Q_{v,io}}^2}{2{S_{io}}^2}\right] + \left[\frac{k_v.L_v.\left(Q_{v,vi}\right)^{1.9}}{(1000.D_{vi})^5} + \zeta_v \frac{\rho^* {Q_{v,vi}}^2}{2{S_{vi}}^2}\right] \qquad (1)$$

with:

$Q_{v,io}$ (m³/h) the flowrate of the fan;

$k_{io} = 3.10^6$ () the linear pressure loss coefficient of the the main duct+supply duct assembly [3];

$L_{io} = \begin{cases} 1. \quad if\ \zeta_p = 0 \\ 1.+0.25 \times L_{tot}\ \ if\ \zeta_p \neq 0 \end{cases}$ (m) the length of the main duct+supply duct assembly;

$\zeta_{io} = 1$ the local pressure loss coefficient of the inlet (outlet);

ζ_p the local pressure loss coefficient of the plenum (***filled in by the user, section 5.4***);

$Q_{v,vi}$ (m³/h) the flowrate of the secondary duct i;

k_v the linear pressure loss coefficient of the secondary ducts (***filled in by the user, section 5.3***);

$L_v = \begin{cases} L_{tot}.if\ \zeta_p = 0 \\ 0.75 \times L_{tot}\ \ if\ \zeta_p \neq 0 \end{cases}$ (m) the length of the secondary ducts;

$\zeta_v = 0.29 \times N_C$ the local pressure loss coefficient relating to the bends of the secondary ducts [3].

5.1.3 Collective system model

Model under development

5.2 Tightness class (*Tightness* column)

A dropdown list in the *Tightness* column is used for defining the system's tightness class under the following standards: EN 12237 [4] and EN 1507 [5].

To take account of leakage in connection with the tightness of the system, a boundary condition is defined at zero pressure, at a temperature equal to the internal temperature and at mass fractions of chemical species equal to the external ones.

At each instant, the flowrate $Q_{v,fuite}$ between this boundary condition and the system is calculated as follows:

$$Q_{v,fuite} = sgn(\Delta P).3600.A_{res}.K_{res}.\left(\frac{\rho^*}{\rho_{ref}}\right)^{(0.65-1)}.|\Delta P|^{0.65} \quad (2)$$

with ρ_{ref} the density corresponding to an ambient temperature of 20°C and ΔP the pressure differential between the system pressure experienced by the air terminals and the boundary condition,

$A_{res} = \pi D_{io} L_{io} + \sum_i \pi D_{vi} L_v$ (m^2) the surface area of the system

and K_{res} a coefficient dependent on the tightness class (Table 7). The values selected for classes A to D are taken from the following standards: [4] and [5]. The value of 0.081 10^{-3} for the NC class corresponds to 3 times that of class A.

Table 7: Tightness class and conventional value of corresponding K_{res}

Tightness class (*Tightness*)	K_{res}
NC	0.081 10^{-3}
Class_A	0.027.10^{-3}
Class_B	0.009.10^{-3}
Class_C	0.003.10^{-3}
Class_D	0.001 10^{-3}

5.3 Roughness of the secondary ducts (*Roughness* column)

The user indicates the roughness of the secondary ducts by filling in the ***Roughness*** column using a dropdown list. The possible values are presented in Table 8 below. The corresponding linear pressure loss coefficients are taken from NF DTU 68.3 [3].

Table 8: Roughness classes of the secondary ducts and corresponding linear pressure loss coefficients

Roughness (*roughness*)	k_v
rigid	3.10^6
flexible	9.10^6

5.4 Pressure loss of the plenum (*Zeta Plenum* column)

The user indicates the local pressure loss coefficient of the plenum ζ_p by filling in the ***Zeta Plenum*** column.

A value equal to 0 indicates that there is no distribution plenum in the system. If no value has been entered, a plenum is taken into consideration and its default pressure loss coefficient is equal to 3. This value, representative of strong values for this type of component, is chosen to enable the valuation of the optimized plenum chambers characterized by testing.

5.5 Diameter of the main duct (*In/Out Diameter (m)* column)

The user indicates the diameter of the main duct D_{io} (m) by filling in the value in the ***In/Out Diameter (m)*** column.

5.6 Diameters of the secondary ducts and main ducts (*Duct Diameters (m)* columns)

The user indicates the diameters of the different secondary ducts D_{vi} (m) by filling in the columns corresponding to the rooms treated by the system.

In the case of an individual system, a single value needs to be indicated.

In the case of a collective system, two values need to be specified, separated by a semicolon. The first value corresponds to the diameters of the secondary ducts and the second value corresponds to the diameters of the main ducts.

6 DESCRIPTION OF THE TERMINAL COMPONENTS (*CATALOGUE* TABS)

The description of the terminal components is in the ***catalogue*** tab.

For each component, the user indicates the desired reference in the ***Reference*** column. This reference will be used to position the component in the building (refer to section 7).

Next, the user defines the type of component (***vent***, ***fan1***, ***fan2*** *or* ***fan3***) using a dropdown list in the ***Component Type*** column.

6.1 Air terminal component type (*Component Type* = *vent*)

6.1.1 Settings

The principle of defining a terminal component of the air vent[1] type consists of providing a module Q_{v0} in m^3/h for a rated operating pressure range within the interval $[Prated; Pauto]$ (Pa) at an ambient temperature of 20°C (Figure 4).

The value of Q_{v0} itself can be a function of a combination of other variables such as the relative humidity (%), volume fraction of CO_2 (ppmv), formaldehyde concentration (µg/m^3) or temperature (°C); it can be varied manually by the occupants or it can be linked to their presence. The available functions are ramps (linear or tophat) or threshold-triggered timers.

By default (when the **Loc** cell is left empty), the sensors providing access to these variables are located in the room where the component is placed.

In the case of sensor used for fan regulation of a centralized system, the sensor is by default placed in the ductwork near the fan (upstream for exhaust fan, downstream for supply fan).

Sensors can also be positioned elsewhere by the user, then the **Loc** cell indicates the location to be considered.

Below, we present the modeling process with several illustrative examples.

6.1.1.1 Self-regulating air inlet

Table 9

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue
EA22	vent		20	100		22					

[1] Here, the term “air vent” is generic, and can refer to an exhaust vent, a supply vent or an air intake.

The data entered in Table 9 is used to model a self-regulating air inlet with a component of the following type: ***vent*** presenting a module of 22 m^3/h in the operating pressure range [20; 100] Pa.

Important: in the generic modeling approach used, the fact that it is an air inlet here is not an intrinsic characteristic of the component; rather, it results from its implementation in the system as described by all of the different tabs in the setup file.

6.1.1.2 Humidity-sensitive air inlet

Table 10

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue
EAH1	vent		20			5;45	ramp	linear	HR		50;65

The data entered in Table 10 are used to model a humidity-sensitive air inlet with a component of the following type: ***vent*** presenting a module at 20 Pa varying linearly from 5 m^3/h to 45 m^3/h dependent on the humidity for a rated operating pressure of 20 Pa.

Important: if there is no value in the Pauto column, the tool automatically considers Pauto=Prated.

Thus, the module is defined in the ***Yvalue*** column by a vector of values separated by a semicolon. The corresponding humidity levels must be defined in the ***Xvalue*** column by a vector of the same dimension.

Important: in this example, 2 points were entered to define the control function, but the tool enables the user to define as many points as wished; the values must simply be separated by semicolons.

The control function resulting from this sample entry is illustrated in Figure 2.

This function was thus obtained by entering ***ramp*** in the ***Type*** column and ***linear*** in the ***Parameter*** column of the controller ***ctrl1****.* For a controller of this type, the ***tophat*** value could also be selected in the ***Parameter*** column. In this example, the function illustrated in Figure 3 would have been obtained.

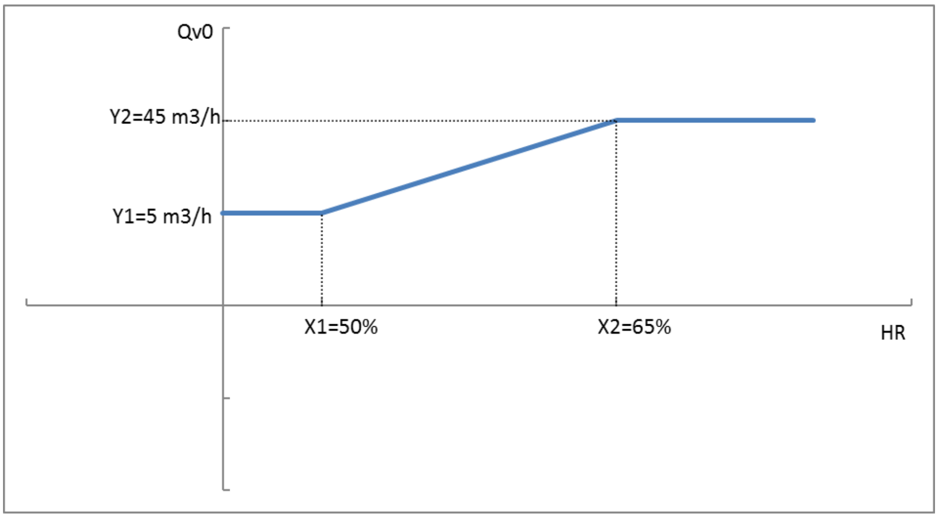

Figure 2: Illustration of the function {ramp; linear} linking the module Q_{v0} to the relative humidity RH *experienced by the component*

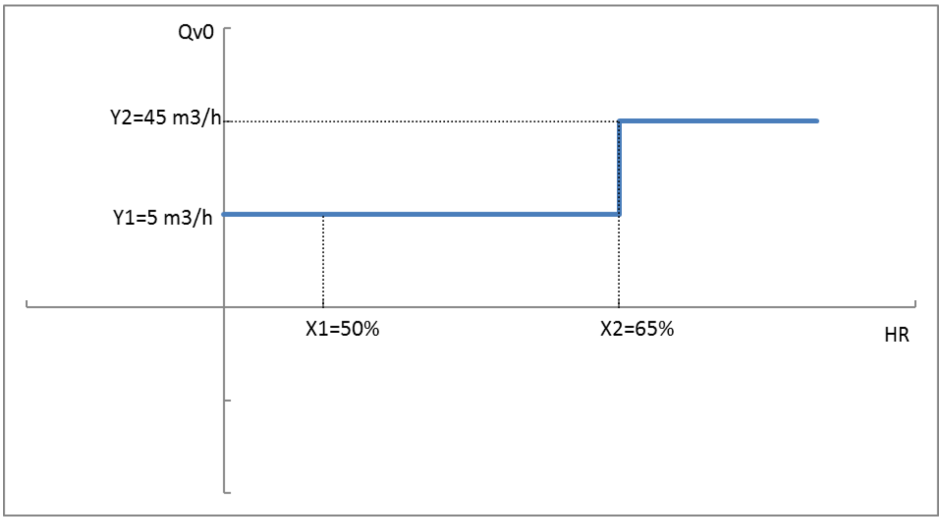

Figure 3: illustration of the function {ramp; tophat} linking the module Q_{v0} to the relative humidity RH *experienced by the component*

6.1.1.3 Timed double flow exhaust vent triggered by occupancy detection

Table 11

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue
TW	vent		80			5;30	timer	30	presence		0;1

The data presented in Table 11 is used to model a timed double flow exhaust vent with a component of the following type: ***vent*** presenting a module at 80 Pa at 5 m^3/h, going up to 30 m^3/h when at least one person is in the room.

The module remains at 30 m^3/h for 30 minutes after the occupants have vacated the room. This time is set by assigning the value *30* to the ***Parameter*** column.

Important: for controllers of the timer type, the Yvalue column can only have a vector with 2 dimensions: the first vector corresponds to the value of the module when the

timer is not activated and the second vector corresponds to the value of the module when the timer is activated. The Parameter column can only have the following values: 0, 10, 20, 30, 40, 50 or 60, indicating the activation time of the controller in minutes after triggering.

Important: when the Quantity column = presence or manual, the Xvalue column can only have the following values: 0 or 1. 0 means that the room is vacant or that manual control is disabled, 1 means that the room is occupied by at least one person or that manual control is enabled.

6.1.1.4 Timed high airflow humidity-sensitive exhaust vent triggered by a CO2 threshold

Table 12

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1						ctrl2					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue	Yvalue	Type	Parameter	Quantity	Loc	Xvalue
HRC02	vent		80		MAX	10;40	ramp	linear	HR		50;80	0;96.2	timer	20	CO2		0;1200

The data presented in Table 12 is used to model a timed high airflow humidity-sensitive exhaust vent triggered by a CO2 threshold. In humidity-sensitive mode, the air vent’s module at 80 Pa varies linearly from 10 m^3/h to 40 m^3/h in a relative humidity range from 50% to 80%. If the volume fraction of CO_2 in the room where the component is located exceeds 1200 ppmv, the module at 80 Pa goes up to 96.2 m^3/h and stays at that level for 20 minutes after the volume fraction has fallen below that threshold.

This is done through an assembly of two controllers: a linear ramp based on RH and a timer based on CO_2. The ***Assembly*** column indicates how to choose one of the two modules calculated by the two different controllers (here, the ***MAX*** value indicates that the maximum of the two values must be considered).

Important: the Assembly column can have the values MAX, MIN, AVERAGE, MULTIPLY or ADD so as to indicate whether to consider the maximum, minimum or the average (or to perform the multiplication or the addition) of the Yvalue calculated by the different controllers. The tool makes it possible to assemble up to 10 controllers in this way, for a given component.

6.1.2 Model

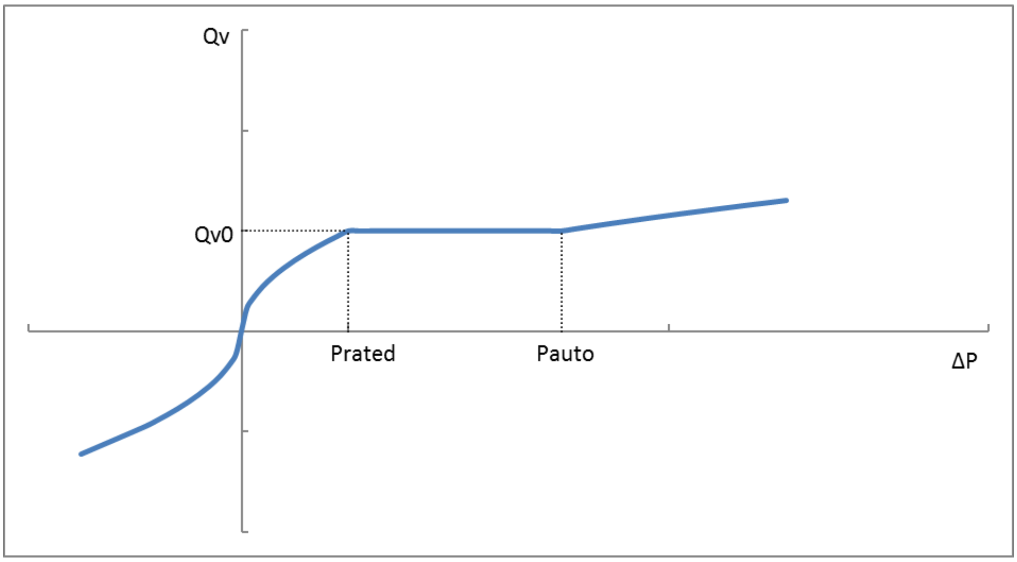

Figure 4: Illustration of the flow/pressure law for a component of the air vent type

The law used for deducing the volume flowrate at time t Qv passing through the component from its operating pressure ΔP is considered quadratic for $\Delta P < Prated$ and $\Delta P > Pauto$ and constant within the range $\Delta P \in [Prated; Pauto]$ (Figure 4)

That is to say:

$$Qv = sgn(\Delta P).K_b.\left(\frac{|\Delta P|}{\rho^*}\right)^n \quad (3)$$

with: $\Delta P = \left(\tilde{P}^i - \rho^i g z^i\right) - \left(\tilde{P}^j - \rho^j g z^j\right)$, where *i* and j represent the nodes placed on either side of the component, and:

$$si\ \Delta P < Prated : \begin{cases} n = 0{,}5 \\ K_b = \sqrt{\dfrac{\rho_{ref}}{Prated}} Q_{v0} \end{cases}$$

$$si\ Prated \leq \Delta P < Pauto : \begin{cases} n = 0 \\ K_b = Q_{v0} \end{cases} \quad (4)$$

$$si\ \Delta P \geq Pauto : \begin{cases} n = 0{,}5 \\ K_b = \sqrt{\dfrac{\rho_{ref}}{Pauto}} Q_{v0} \end{cases}$$

with Q_{v0} the module as defined by the user (see section 6.1.1) and ρ_{ref} the density corresponding to an ambient temperature of 20°C.

6.2 Fan (ventilation group) component type (*Component Type = fan1, fan2 or fan3*)

6.2.1 Settings

A fan is defined in two stages.

The first stage consists of filling in the characteristics of the type of unit to which the fan belongs, using one of the tabs ***fan1***, ***fan2*** or ***fan3***.

These are used to indicate how the two fans (supply and exhaust) of the unit are controlled (flowrate or speed control), and, where applicable, the efficiency, the internal leak rate and the bypass temperature of the heat exchanger. The user also specifies the laws that are applied to link the total pressure and the power consumption of the fan to its flowrate. The characteristics of each speed are entered, starting with the smallest rotational speed. For each speed, the first point is the one that supplies the pressure at zero flowrate and the last point is the one that supplies the maximum flowrate for zero pressure. Cells without information for the lowest speeds are filled in with zeros (see table 14).

The second stage consists of defining one or several components of the selected type (***fan1***, ***fan2*** or ***fan3***) in the ***catalogue*** tab. A component then represents one of the fans of the unit associated with a given setting (flowrate or speed set-point). The fan will determine if it is a supply fan or an exhaust fan of the unit, depending on its position in the building (see section 7).

The various controllers of the component are used for defining its set-point. The principle of use is similar to what we presented earlier for the components of the air vent type, except that:

- for a speed-controlled fan: the ***Yvalue*** column represents the number of the speed to use, in other words that of the corresponding flow/pressure curve in the unit type tab (***fan1***, ***fan2*** or ***fan3*** tabs);
- for a flow-rate-controlled fan: the Yvalue column represents the flowrate set-point (in m3/h) transmitted to the fan. The "flowrate" option for fan control should be selected to enable modelling constant flow systems.

Below, we present the modeling process with several illustrative examples.

6.2.1.1 Two-speed single flow exhaust unit

The tables below present the settings of the ***fan1*** tab, representing a single flow exhaust unit here.

Therefore, only the parts corresponding to the exhaust fan are filled in ***EXHAUST*** line of the table describing the fan control mode (Table 13) and ***EXHAUST FAN*** table providing the operating curves (Table 14).

As this is a speed-controlled fan, the ***Fan control*** column is set to ***speed***. Columns 1 and 2 of the ***EXHAUST FAN*** table are filled in to provide, for each speed and as a function of the flowrate, the total pressure of the fan and its power consumption.

Table 13

	Fan control	Heat Exchanger Efficiency	Heat Exchanger Leak	Heat Exchanger Bypass
SUPPLY	___			
EXHAUST	speed			

Table 14

EXHAUST FAN	1		2	
Flowrate (m3/h)	Pressure (Pa)	Energy Consumption (W)	Pressure (Pa)	Energy Consumption (W)
0.00	136.94	11.17	142.70	18.56
50.00	120.72	11.35	130.45	19.37
100.00	112.07	12.34	134.78	20.99
125.00	90.81	13.51	135.14	22.43
150.00	0.00	15.41	132.25	23.51
200.00	0.00	0.00	120.72	26.04
250.00	0.00	0.00	89.73	30.09
260.00	0.00	0.00	0.00	31.00

Important: the tool allows you to set 5 speeds and 20 operating points per speed.

Important: for each speed, the operating point must be set to zero flowrate and the operating point must be set to zero pressure. There must not be lines containing zeros in all of the columns.

Table 15 below presents the setup of the component corresponding to the unit’s fan.

Table 15

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue
EasyHomeC	fan1					1;2	timer	0	manual	Kitchen	0;1

The ***Component Type*** column takes the ***fan1*** value corresponding to the previously set tab. In this example, the associated controller indicates that speed no. 2 is activated manually by the occupants when one of them is in the kitchen.

6.2.1.2 Double flow exhaust unit

The tables below present the settings of the ***fan1*** tab, representing a double flow exhaust unit here.

Therefore, the two parts, corresponding to the supply fan and the exhaust fan, are filled in (see Table 16). The exhaust fan is speed-controlled (***speed***) and the supply fan is flowrate-controlled (***flowrate***). The unit is equipped with a heat exchanger. Its efficiency (***Heat Exchanger Efficiency*** column) is set to 90% and its internal leak rate is set to 1.7% (***Heat Exchanger Leak*** column). These values must be expressed as a fraction. The outdoor temperature threshold used to bypass the heat exchanger is set to 16°C (***Heat Exchanger Bypass*** column).

Table 16

	Fan control	Heat Exchanger Efficiency	Heat Exchanger Leak	Heat Exchanger Bypass
SUPPLY	flowrate	0.9	0.017	16
EXHAUST	speed			

Table 17 below presents the settings of two components corresponding to the unit's fans. The exhaust fan, Fex, is controlled with a single flowrate-pressure curve. Therefore, its speed is constant, set to 1. The flowrate of the supply fan, Fsu, is coupled to the exhaust flowrate. The location of the control element is indicated in the "**Loc**" column. Its coupling coefficient is equal to 99%. The control function expressing this coupling coefficient is defined by a linear ramp with a slope equal to 0.99, within a flowrate range of the exhaust fan set here from 0 to 1000 m^3/h, i.e. a range that is large enough to easily accommodate the unit's scope of use.

Important: a fan may only be coupled with the flowrate of a fan belonging to the same type of unit (fan1, fan2 or fan3).

Table 17

Reference	Component Type	Ctol	Vent pressure		Assembly	ctrl1					
			Prated	Pauto		Yvalue	Type	Parameter	Quantity	Loc	Xvalue
Fsu	fan1					0;990	ramp	linear	Qv	Fex	0;1000
Fex	fan1					1					

6.2.2 Model

6.2.2.1 Fan model

The fan model is defined directly by entering various pressure curves $\Delta P_v = f_v(Q)$ according to the rotational speed *v* of the fan (continuous curves in Figure 5).

A quadratic local pressure loss is applied, in order to account for potential situations in which the pressure gain or flowrate is inversed (dotted curves in Figure 5).

The system of equations is then increased by one equation per fan in which the unknown variable, the flowrate, is resolved by the solver so that the pressure gain ΔP_{gain} generated by the fan is balanced by the pressure differential between the fan's upstream and downstream area ΔP.

For a given rotational speed *v*, the pressure gain ΔP_{gain} (Pa) generated by the fan is ultimately written as follows:

$$\begin{aligned} &if\ Q < 0: \quad \Delta P_{gain} = f_v(0) + \zeta \frac{\rho^* Q^2}{2S^2} \\ &if\ Q > 0\ and\ \Delta P < 0: \quad \Delta P_{gain} = f_v(Q) \\ &if\ \Delta P > 0: \quad \Delta P_{gain} = -\zeta \frac{\rho^* Q^2 - Q_{fv=0}^2}{2S^2} \end{aligned} \qquad (5)$$

With ζ the local pressure loss coefficient of the fan set to 1000, its section *S* defined automatically to correspond to the diameter of the duct leading to the fan and $Q_{fv=0}$ the flowrate for which the function $f_v(Q)$ cancels itself out.

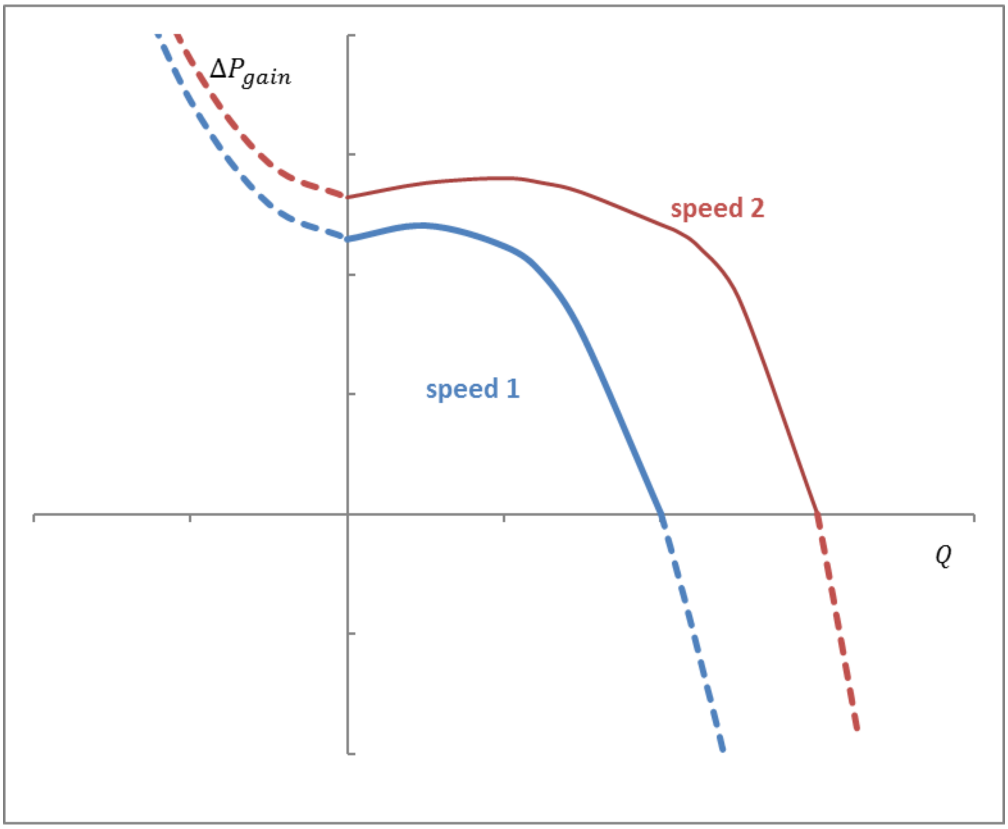

Figure 5: Example of curves characteristic of a fan

6.2.2.2 Exchanger model

An exchanger can be associated with the supply fan of a ventilation unit. It is defined by an efficiency rate η_T and an internal leak rate η_{vi}.

In the presence of an exchanger with a non-zero efficiency, a boundary condition replaces the external condition upstream from the supply fan. The pressure and the mass fractions of the chemical species of this boundary condition are set as being equal to the external ones. The temperature T_{supply} of this boundary condition is defined as being equal to:

$$T_{supply} = T_{ext} + \eta_T (T_{exhaust} - T_{ext}) \quad (6)$$

With $T_{exhaust}$ the indoor temperature of the building and T_{ext} the outdoor temperature.

In order to take account of a non-zero internal leak rate, a leak flowrate Q_{leak} is imposed from the node upstream from the exhaust fan to the node downstream from the supply fan. This flowrate is equal to:

$$Q_{leak} = \eta_{vi} Q_v \quad (7)$$

With Q_v the flowrate of the fan.

The tool gives the possibility to model the exchanger by-pass by removing the temperature gain on a threshold criterion on T_{ext} . This threshold criterion is set by the user in the template.

6.3 Taking account of the production tolerances

In the tab catalogue, the ***Ctol*** column defines, for each component, a tolerance class to be taken into account for the component.

At this stage, pending the choice of the end user, three options are available:

- *certified*: a tolerance representative of those used for product certification tests is taken into account;
- *Important*: a greater tolerance than those used for product certification tests is taken into account;
- *rated*: the rated characteristics of the component are taken into account (no variation linked to the production tolerance).

The tolerance values mentioned are proposals that need to be validated by the certification project stakeholders.

These tolerance classes apply differently depending on the type of component, see section 6.3.1 and section 6.3.2 below.

Important: if nothing is specified, the tool considers that Ctol is set to rated.

6.3.1 Case of vent components

A *Ytol* coefficient is drawn randomly for each simulation case in accordance with a uniform law between two bounds [Ytolmin, Ytolmax] defined as a function of the component's tolerance class. This coefficient is then used as a multiplying factor of the component's module. Bounds proposals are made in table 18.

Table 18: Bounds of variation of the Ytol coefficient representing the production tolerance of vent components

Ctol	***Ytolmin ()***	***Ytolmax ()***
certified	1.	1.3
NC	0.7	1.3
rated	1	1

6.3.2 Case of fan components types

A pressure *Ptol* (Pa) is drawn randomly for each simulation case in accordance with a uniform law between two bounds [Ptolmin, Ptolmax] defined as a function of the component's tolerance class. This pressure is added to the operating curves defined by the user. Bounds proposals are made in table 19.

Table 19: Bounds of variation of the Ptol coefficient representing the production tolerance of vent components

Ctol	***Ptolmin (Pa)***	***Ptolmax (Pa)***
certified	-5	15
NC	-10	30
rated	0	0

7 PLACEMENT OF THE TERMINAL COMPONENTS IN THE BUILDING (*SUPPLY* AND *EXHAUST* TABS)

Once all of the components of the ventilation systems have been defined, the user specifies, for each type of building, their locations using the ***supply*** tabs (for supply components) and the ***exhaust*** tabs (for exhaust components).

The first column of each tab, called ***select*** and set to ***yes*** by default, enables the user to restrict the scope of use of the system by setting it to ***no*** for types that are not included. To prevent the risk of inconsistency between the two tabs, we advise, for example, to select the types in the ***supply*** tab and then to copy/paste the values from the entire ***select*** column to the ***exhaust*** tab.

Important: if the Select columns of the two tabs are inconsistent, the tool indicates an error message when the calculations are launched.

The user places the components using a dropdown list displaying the list of component references previously selected in the tab catalog.

The ***ductwork*** column is for selecting, where applicable, the fan used in the system. In this case, the reference must have a ***fan1***, ***fan2*** or ***fan3*** component type.

The other columns (***Hall, Living, Bedroom, Kitchen, WC, Bathroom*** and ***Bathroom-WC***), represent the rooms and can take all types of components (***vent***, ***fan1***, ***fan2*** or ***fan3)***.

Table 20 and Table 21 present as examples the placement in the building of the components of a single flow exhaust mechanical ventilation system.

Table 20: Placement of supply components for 2-bedroom housing units

Select	Dwelling		ductwork	hall	Living	Bedroom	Kitchen	WC	Bathroom	Bathroom-WC
yes	F3	0W-0B-1BW			EA45	EA30				
yes	F3	1W-1B-0BW			EA45	EA30				
yes	F3	1W-2B-0BW			EA45	EA30				
yes	F3	2W-1B-0BW			EA45	EA30				
yes	F3	1W-1B-1BW			EA45	EA30				
yes	F3	1W-0B-1BW			EA45	EA30				

Table 21: Placement of exhaust components for 2-bedroom housing units

Select	Dwelling		ductwork	hall	Living	Bedroom	Kitchen	WC	Bathroom	Bathroom-WC
yes	F3	0W-0B-1BW	EasyHomeC				BEK2			BEB2
yes	F3	1W-1B-0BW	EasyHomeC				BEK2	BEW2	BEB2	
yes	F3	1W-2B-0BW	EasyHomeC				BEK4	BEW4	BEB4	
yes	F3	2W-1B-0BW	EasyHomeC				BEK4	BEW4	BEB4	
yes	F3	1W-1B-1BW	EasyHomeC				BEK4	BEW4	BEB4	BEB4
yes	F3	1W-0B-1BW	EasyHomeC				BEK2	BEW2		BEB2

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