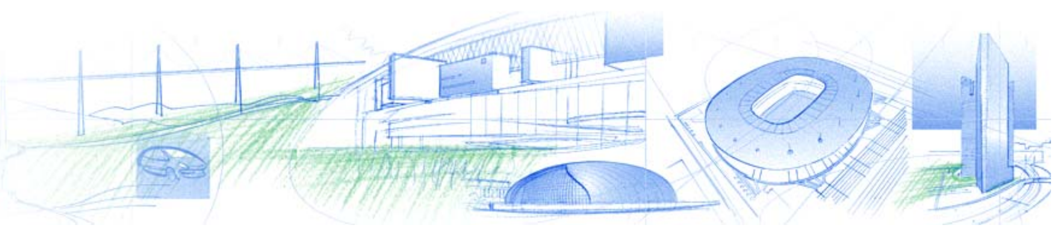

EC-RESHYVENT project

WP 7: Ventilation and control strategy support unit

Ventilation control strategies

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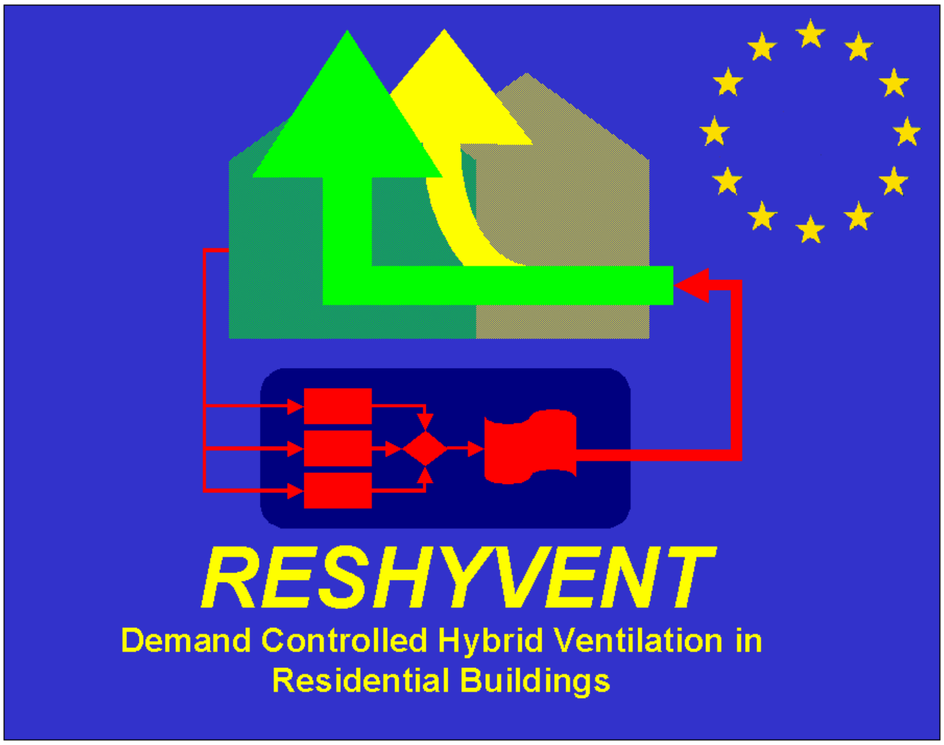

PREAMBLE

INITIAL OBJECTIVES OF THE WORK PACKAGE

The integration of natural ventilation and mechanical driving forces in a hybrid ventilation system requires development of new ventilation control strategies. The objective is to develop strategies for control of hybrid ventilation systems at any time and for a certain combination of internal pollutant, outdoor conditions and comfort requirements that ensure that the immediate demands to the indoor environment are fulfilled in the most energy efficient manner.

The different specific objectives of the work have been organized in different tasks.

Task 7.1: Definition and analysis of ventilation strategies for hybrid systems
A basic condition for a well working hybrid ventilation system is a ventilation strategy, which fulfils the basic needs of the occupants regarding IAQ and thermal comfort.

Task 7.2: Definition and analysis of control parameters for hybrid ventilation
The research will focus on analysis of relevant control parameters. Attention has to be taken to indoor air quality and related parameters (CO_2, H_2O, Radon etc.) and thermal comfort during summer and winter.

Task 7.3: Hybrid ventilation control strategies
Analysis of existing and development of new control strategies for hybrid ventilation.
Improvement of existing control strategies in retrofit of residential buildings.

PROPOSED AIMS

The first work of the group showed that it was illusory to try to be exhaustive in the development of ventilation and control strategies. The document draws up a panorama of the principles to take into consideration when developing ventilation strategies together with its control strategies. It is important to draw the attention of the reader that in some cases the ventilation strategies do not include strictly speaking a control strategy involving a separate control system.

A methodology to develop control strategies is also provided together with example of applications for new hybrid control strategies.

Particular strategies are developed with Industrial Consortium who needed assistance. The work with the IC's is subjected to confidential reports. General principles and examples of hybrid ventilation control strategies from these works are added in this document.

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PART 1

GENERAL CONSIDERATIONS FOR DEVELOPMENT OF HYBRID VENTILATION SYSTEMS

1 INTRODUCTION

A building is a system with a variety of physical processes interacting with each other and with the environment. From the control point of view, it is considered as a having multi-variant dynamic subsystems showing various linear or non-linear behaviours. Environmental and occupancy changes in a building increase the complexity of control operations. Occupants not only impose control goals but also influence building processes thus impacting indirectly on the control functions of different processes.

HVAC systems have to be controlled to satisfy the requirements of occupants under the different states of the environmental factors. In general the control goal of the HVAC system is to minimize energy consumption while guaranteeing occupant's comfort and being cost effective. In many cases however, cost effectiveness does not imply reduction of energy consumption, for example when control is optimised with respect to electricity tariffs. The control goals will be:

1. to meet building demands
2. to use the less expensive energy first
3. to meet the constraints regarding peak power for each energy
4. to store energy or use stored energy when it is wise.

Hybrid ventilation systems combine the use of natural ventilation systems and mechanical ventilation systems. It takes maximum benefits of .natural driving forces to reduce energy consumption while maintaining occupant comfort in terms of indoor air quality or thermal aspects.

Natural ventilation systems include

- Permanent openings for background ventilation
- Controllable openings (manual and/or automatic) to adjust ventilation needs

Mechanical ventilation systems include, in addition to the above:

- Fans for supply and/or exhaust

Thus, in hybrid ventilation, the transitions between natural and mechanical ventilation modes have to be clearly defined.

In order to assess the impact of the ventilation control strategy, the following issues must be taken into account:

- the different types of pollutant sources
- occupant health and comfort
- building materials conservation
- energy consumption

This first part of the document deals with the above general aspects to be taken into account while developing hybrid ventilation and control strategies.

2 POLLUTANT SOURCES

The pollutant sources can be separated into 2 main categories

- Outdoor pollution
- Indoor pollution

Humidity is not a direct pollutant; but has an impact on some of them, and to building conservation (house dust mite and mould risks).

2.1 OUTDOOR POLLUTION

Even if theoretically, the ventilation flow could be adjusted with respect to outdoor pollution level (for example by reducing air flow at period of high level of pollution), it is difficult to apply in practice for the following reasons:

- There are different kinds of outdoor pollutants with different scenarios of occurrence which still need further investigation.
- Their monitoring remains difficult and/or expensive (measurements issues).
- Competition would exist between the impact of internal versus the impact of external pollutant, with no clear rationale basis today to make a decision.

Accidental outdoor pollution

It appears that this issue would be more considered as a system design issue: for example, choice of a balanced system, position of air intake, filtering…except in case of control of a filter or air treatment device via for example a air handling unit.

2.2 INDOOR POLLUTION

The sources differ according to their production in space and in time

- Building related pollutant can be considered as occurring everywhere with a quite constant level
- Human presence related pollutants occur of course where people are
- Activities pollutants are in given spaces and, occur for a sharp increase and short term production schedule in most cases.

3 OCCUPANT HEALTH AND COMFORT

Occupant health and comfort can be addressed as follows

- Hygrothermal comfort
- Acoustic comfort
- Visual comfort
- Olfactory comfort
- Heath impact of pollutant

Visual comfort is not directly related to ventilation, and acoustic must be taken into account as a possible side impact.

3.1 HYGROTHERMAL COMFORT

Ventilation system has an impact:

- on draught risks: depending on air velocity and temperature in the occupied zone
- on indoor temperature in free floating situation
- on indoor humidity (dryness feeling)

The draught issue is considered as part of the system design. The system should aim to avoid nuisance draughts (likely to disturb papers for example). Local air velocities (in summer) should be below 0.8 m/s. ISO 7730 [1] recommends that for moderate thermal environments with predominantly sedentary activity, the mean air velocities during cooling should be less that 0.25 m/s in summer, whilst in winter they should be less than 0.15 m/s [2]. In the case of hybrid ventilation, this issue will be considered if there is a possibility to preheat the incoming air.

In heating or cooling mode, it can be assumed that the heating cooling system can offer the possibility to reach the set point. On the opposite, in free running conditions, the air flow will drive the indoor temperature and therefore must be part of the ventilation strategy

The humidity is mainly related to dryness feeling. As the humidity level results from outdoor humidity level, indoor water vapour production and flow rates, the air flow as an impact. Another possibility is to install a humidification system, and its use has to be then a part of the ventilation strategy.

Low humidity levels can cause dryness or skin irritation. There is rarely any problem, if the humidity level remains within a range of 30% to 70%.

3.2 ACOUSTIC COMFORT

Ventilation system can impede acoustic comfort as follows:

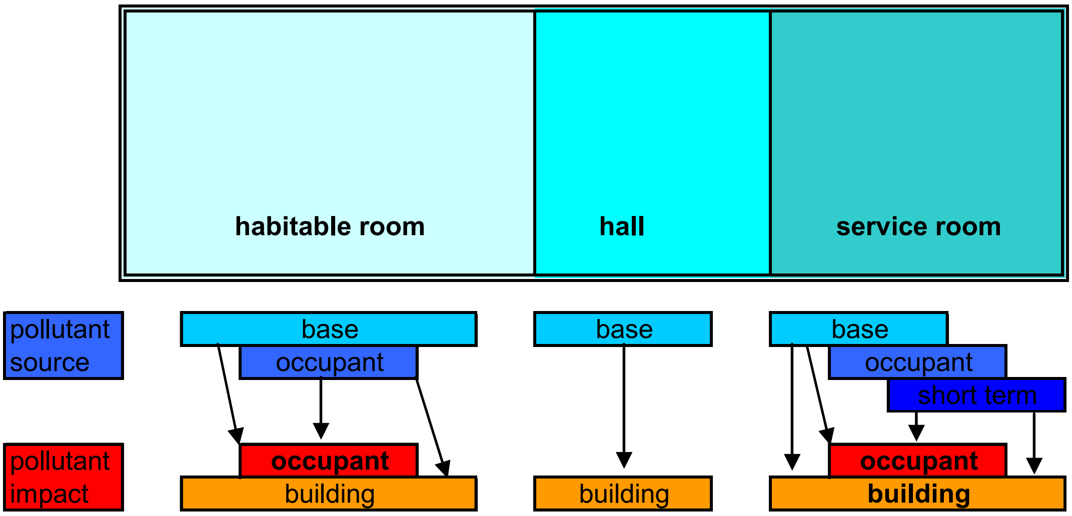
- Transmitting outdoor noise
- Transmitting noise between a dwelling and other dwelling or central circulation
- Transmitting noise between rooms
- Noise generated by the system outlet, fans

Except for the possible impact on windows opening we propose to consider that it is art of the system design (e.g.; not considering that the occupant could stop the system because of its own noise).

3.3 OLFACTORY COMFORT AND HEALTH IMPACT OF POLLUTANTS

The olfactory comfort is the individual's perception of air quality within the building. It varies within the building and with time since it depends on many factors such as: indoor and outdoor pollution levels, humidity level ventilation flow rate.

Poor indoor air quality leads to occupants' complaints such as headaches, tiredness, dry throat, nasal problems… which are commonly termed as Sick Building Syndrome.



4 BUILDING MATERIAL CONSERVATION

At the building level, the impact of humidity has to be considered everywhere and every time.

For condensation risks, the impact is not only related to humidity level, but also to indoor and outdoor temperature, building envelope characteristics (insulation, air flows in the walls) and system over or under pressurisation.

5 ENERGY CONSUMPTION

Energy impact of ventilation is related to heating, cooling and fan energy. It is related to

- air flow rates which interfere in energy and mass conservation in the zone or building.
- humidification
- indoor air preheating,
- use of controllable heat exchanger,
- use of fans to drive air flows.

PART 2

HYBRID VENTILATION CONTROL STRATEGIES

1 INTRODUCTION

Hybrid ventilation control strategies make use of both natural ventilation systems and mechanical ventilation systems. Such systems work at "low pressure" and are very sensitive to any direct or indirect interaction with the occupants.

In this part of the document, the occupant behaviour issue will be addressed prior to description the ventilation and control strategies as well as description of sensors and actuators.

2 ON THE OCCUPANT BEHAVIOUR WITH RESPECT TO CONTROL

The control strategy will have an impact on the comfort of the occupant and this will obviously lead to some direct or indirect interactions between the system and the occupant.

The definition of a "standard occupant" does not exist. Although it is possible to agree on what is clearly uncomfortable for the occupant, it is difficult to define exactly his priorities. These will vary from one occupant to another one and can vary in time for the same occupant. For example some can be really interested in energy savings, and some prefer a better indoor climate even if it requires energy and is more costly.

Therefore, it is important for any control strategy to be accepted by the occupant that the latter should have the possibility to adapt the system behaviour to his will according to his feeling. Besides research has shown that occupants are more willing to accept a wider comfort band if have control over a local area.

Note that the occupant will react to a need (a specific condition) but not on the disappearance of that condition. For example if an occupant detects tobacco smoke he puts the "supplementary airflow" on but is not likely going to return "normal flow" when smoke disappears.

On the opposite, the occupant is not directly sensible to many points (risks of condensation in building fabrics for example), or unable to predicted the impact of an action (for example, whether increasing ventilation at night will improve the comfort next day during summer period)

Another point is that the control must easily understandable for the user, and that it should feel directly or indirectly the impact (for example a moderately noisy high speed in a kitchen may be not a bad design).

Following the above considerations, the control strategy should include the following criteria:

- It must allow for manual override.
- In the automatic mode, it should give access to the user to modify some set point.
- Once in the manual mode, it should provide rules to switch back to automatic mode
- Auto-learning capabilities might improve the functioning of the control strategy

3 ANALYSIS OF HYBRID VENTILATION FOR CONTROL PURPOSES

The control strategy must account for the fact that in many cases the occupant can control the system independently either locally (in one room) or on a central component.

On main problem in the control strategy where the occupant has a major role: there is a high risk of losing control.

Hybrid ventilation aims at reducing energy consumption and in this context it is wise to consider the direct interaction of the ventilation system with the heating or cooling system. If window opening is for example one means of ensuring natural ventilation, it might be useful that in this functioning mode, the heating system is reduced or switched off. The control strategy may thus include communication signals with other applications [3].

To achieve the control goals of hybrid ventilation, it is critical:

- to define change-over between natural and mechanical ventilation
- to determine whether a concurrent system is an alternative (for example, the mechanical system is run continuously in some cases)

The control strategy should include means to manage pollutant levels. The most common techniques are dilution and extraction for indoor sources of pollutions and filtration for outdoor pollution. In general, dilution techniques are most widely used in residential buildings. Thus air flow rates must abide to a certain background rate to keep an ongoing dilution process.

A few control options that would work with most types of ventilation systems:

- Twenty-four hour timers allow the occupants to set certain times for ventilation. The timer is set to run the fan at least eight hours a day.
- Twist timers also called interval timers, allow occupants to engage fans whenever it is needed. Twist timers can be set up to 60 minutes and are generally located in bathrooms, utility rooms or kitchens.
- Speed controllers allow fan to operate at low speed for background ventilation with a manual high speed boost
- Indoor air quality sensors activate a fan when they detect carbon monoxide, formaldehyde or other pollutants
- Humidity controllers engage a fan on rising humidity. Note that relative humidity is not always a reliable indicator.
- Continuous operation with manual on-off switch

4 CONTROL PARAMETERS

The control parameters are the basis for the strategy definition. A control parameter is any kind of information which could have an impact on the ventilation strategy. The information can be obtained directly by means of dedicated sensors or derived from a set of conditions. The occupant behaviour must be included in the scheme. The control parameters include:

- Outdoor climate (temperature, humidity, pollutant level)
- Building or component characteristic (opening windows, using hot water, switching on lighting…)
- Ventilation system: airflows, pressure difference…
- Indoor temperature (free running)
- Odours in service rooms (kitchen, toilets),
- Humidity in service rooms (kitchen, bathroom)
- Occupancy in habitable rooms (presence, or indirectly by CO_2 level, humidity level, …)

The use of control variables depend on the type of control strategy that will be implemented.

5 DEFINITION OF VENTILATION STRATEGIES

5.1 SPATIAL STRATEGY

The spatial strategy is closely related to the system design and has to be considered at early design phase. The following can be considered.

Outdoor air enters in habitable rooms and is extracted in service rooms with the following aims:

- to limit the overall air change rate witch is favourable to energy impact and should not be a problem as occupant presence is shorter in service rooms than inhabitable rooms
- to limit, to a certain extent the diffusion of short term pollutant produced in service rooms to habitable rooms

Nevertheless, this strategy has the drawback of increasing the air change rate in habitable rooms to unnecessary level when high levels of extract air flow is required in a given service rooms. In this case, a direct par of outdoor air entering the service room could be more efficient. Another point part of the system design is the direct extraction of spot pollution in service rooms

<u>Note about influence of outdoor climatic conditions</u>

Outdoor climatic conditions (outdoor temperature and wind speed) can roughly interfere with the ventilation system through the inlets and the cracks of the envelope.

Examples of flows obtained with an extract only ventilation system are given hereafter for 3 dwelling:

- a 3 storeys dwelling
- a 2 storeys dwelling
- a dwelling built at street level

In each building, each level is identical a symmetrical. The airthightness can vary but the cracks are iso-distributed on each façade at each level (at 1/3 and 2/3 of the ceiling height following the assumptions of IEA annex 27 [4]).

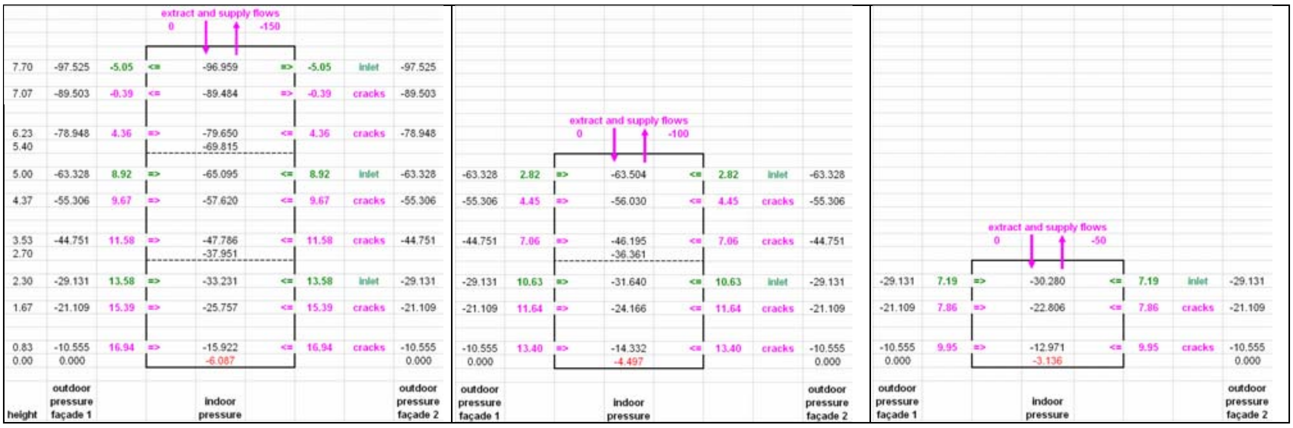
An Excel® model has been realised and examples for 3 ventilation systems are shown below.

- Volume of each storey: 150 m3
- Air tightness: n50 = 2
- Mechanical extract flow : 50 m3/h by floor (mechanical supply = 0)
- Indoor temperature: 20 °C
- Outdoor temperature: 0 °C
- No wind

Ventilation system 1

Self regulated inlets 30 m3/h at 20 pascals (constant flow = 30 m3/h above 20 pascals)

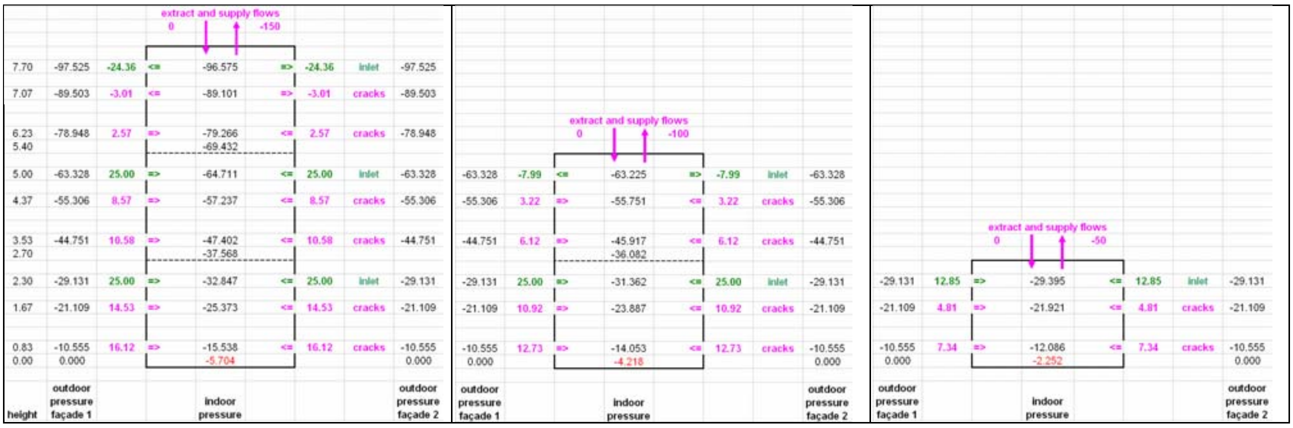
3 storeys dwelling	*2 storeys dwelling*	*1 storey dwelling*



Ventilation system 2

Self regulated inlets 25 m3/h at 1 pascal (constant flow = 25 m3/h above 1 pascal)

3 storeys dwelling	*2 storeys dwelling*	*1 storey dwelling*



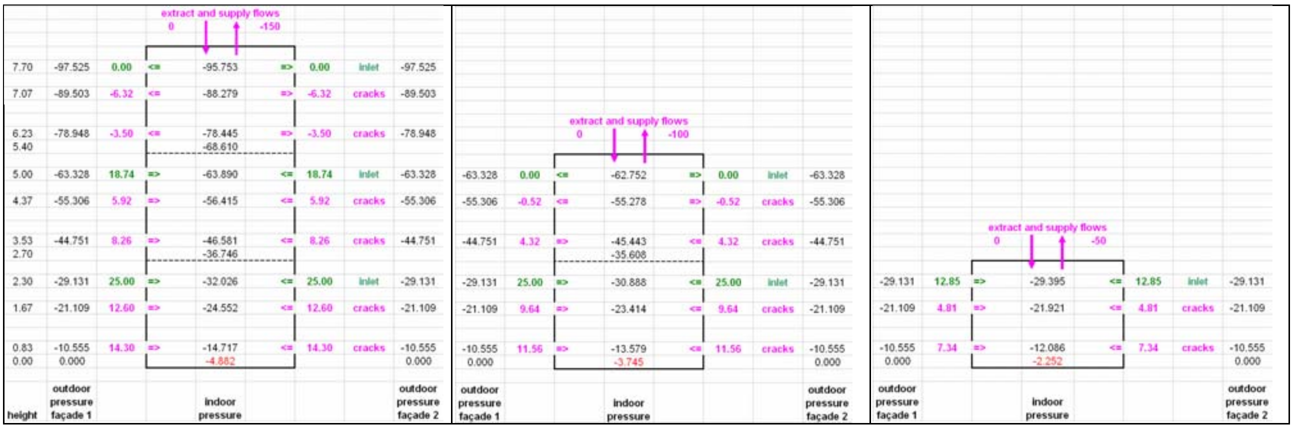
Remark : increasing the inlet size doesn't necessarily increase the fresh air flow (e.g. : fresh air at the upper level of the two storeys dwelling and the three storeys dwelling).

Ventilation system 3

Self regulated inlets with anti reverse flow system 25 m3/h at 1 pascal

(no flow for negative pressure - constant flow = 25 m3/h above 1 pascal)

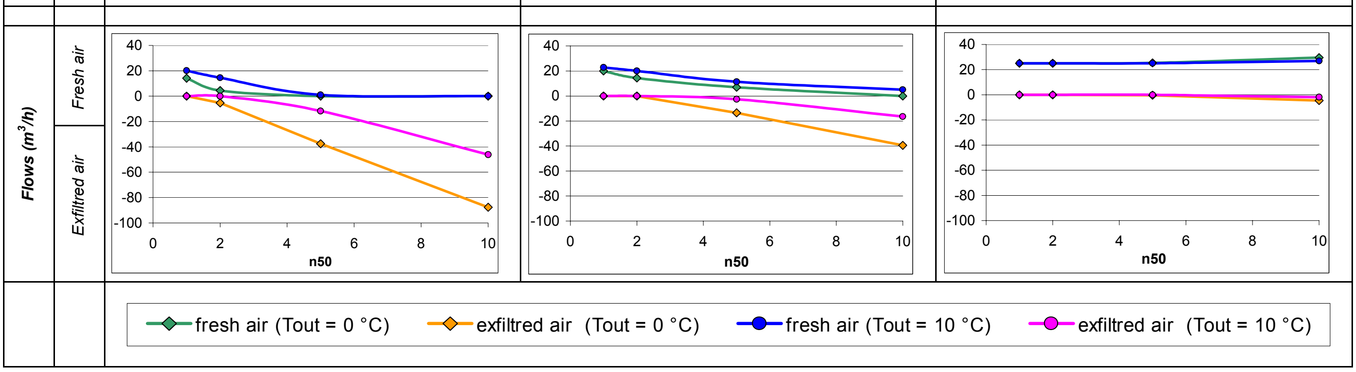
3 storeys dwelling	*2 storeys dwelling*	*1 storey dwelling*



Ventilation system 1

Self regulated inlets 30 m3/h at 20 pascals (constant flow = 30 m3/h above 20 pascals)

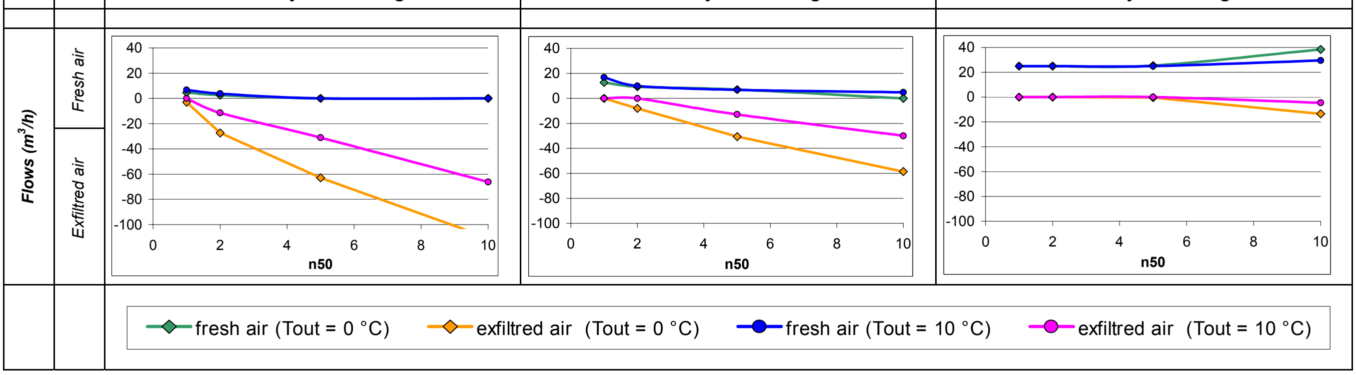
		3 storeys dwelling	*2 storeys dwelling*	*1 storey dwelling*



Ventilation system 2

Self regulated inlets 25 m3/h at 1 pascal (constant flow = 25 m3/h above 1 pascal)

		3 storeys dwelling	*2 storeys dwelling*	*1 storey dwelling*



Ventilation system 3

Self regulated inlets with anti reverse flow system 25 m3/h at 1 pascal

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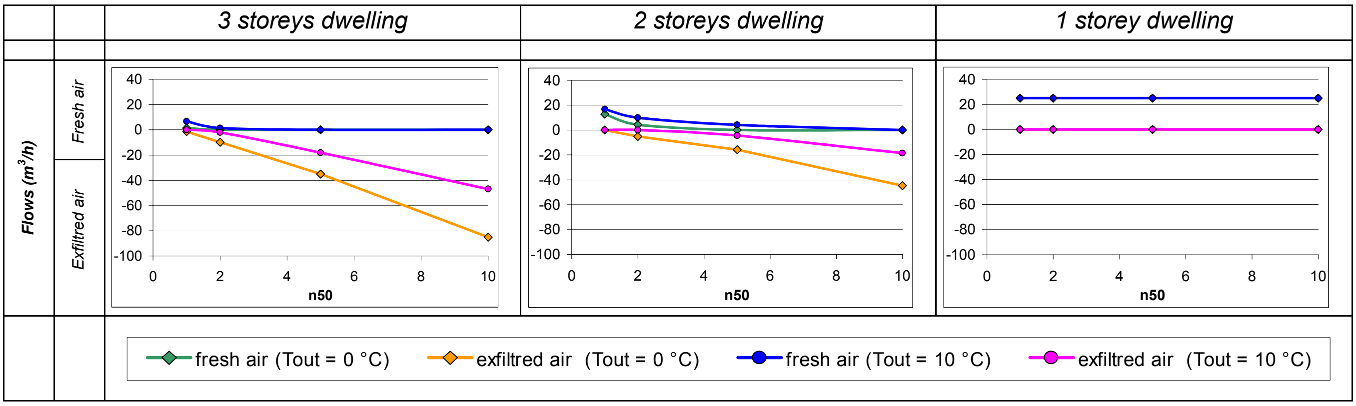


Remark : when the n50 is greater than 2 the airflow of fresh air is very low at the upper floor.

5.2 TEMPORAL STRATEGY

The temporal strategy can be related on one hand to presence of occupant and the pollutant emission due to metabolism and/or activities, and on the other hand by climatic conditions. It is closely linked to demand controlled ventilation and require in general an associated control system.

Flows can be controlled by:

- Presence: movement sensors, clocks, combination with light switch…
- Metabolism:
  - o CO_2
  - o Water vapour
  - o Odours (characterised by the Olf and Decipol concepts introduced by Fanger [5])
- Activities :
  - o Cooking (CO_2 if gas appliances and/or water vapour)
  - o Bath and shower (water vapour)
- Climatic conditions
  - o outdoor temperature
  - o indoor temperature
  - o wind speed
  - o wind direction

The control strategy can be based in general on CO_2, COV, humidity and temperature or a mix of these control parameters.

The different sensors are suitable in different rooms in a residential building.

Room	Control parameter		
	RH	CO_2	VOC
Living room		✓	✓
Kitchen	✓		
Bedroom		✓	
Bathroom	✓		
Toilet			✓

Table 1 : Control parameter following the type of room (IEA annex18 [6])

Similarly following the type of room, different options are available for presence detection in the control strategy. They are summarised in the table below

Room	Type of control strategy			
	Manual	Use of artificial light switch	Presence detection	Timer
Living room	✓		✓	✓
Kitchen	✓			
Bedroom	✓			✓
Bathroom		✓		
Toilet		✓	✓	

Table 2 : Control strategy following the type of room(IEA annex18 [6])

5.3 VENTILATION STRATEGY RELATED TO IAQ AND BUILDING IMPACT

	IAQ	**Building impact**
Inoccupation	Theoretical no, but : 	Minimum ventilation to avoid condensation depending on temperature (indoor and outdoor), humidity production, insulation
Occupation	Ventilation according to pollutant production due to occupant and their activities	In principle no condensation risks if ventilation rate provide IAQ for the occupants
Short term pollutant production	Ventilation for toilet, Higher ventilation for cooking product exhaust, …	High ventilation rate for humidity production

Start occupation period :

minimum ventilation rate when unoccupied

or

restore ventilation before occupancy (the main drawback of this option is the possibility to determine beforehand occupancy in residential building) and higher ventilation rate just after occupancy

5.4 VENTILATION STRATEGY RELATED TO ENERGY

It is useful to think of the control strategy of hybrid ventilation with links to control of heating and/or cooling systems for energy consumption reduction.

Heating mode (must be determined by heating/cooling system)		Lower ventilation rate if Tout < Tin Increase if Tout > Tin (theoretical)
Free running conditions	Intermediate season	No specific strategy
	Summer (without cooling)	Lower ventilation rate if Tout > Tin Increase ventilation rate if Tin > Tout
Cooling mode (must be determined by heating/cooling system)		Lower ventilation rate if Tout < Tin
Fan(s)		Lower fan speed if possible And duration of use

6 TYPES OF CONTROL SYSTEMS

The control systems have to ensure that the appropriate actions are taken to maintain the controlled variables to a value defined by a set point.

HVAC control and building automation is in general quite straight forward. Although heating and air-conditioning make use nowadays of more and more complex control loops, ventilation systems still require relatively standard control loops namely:

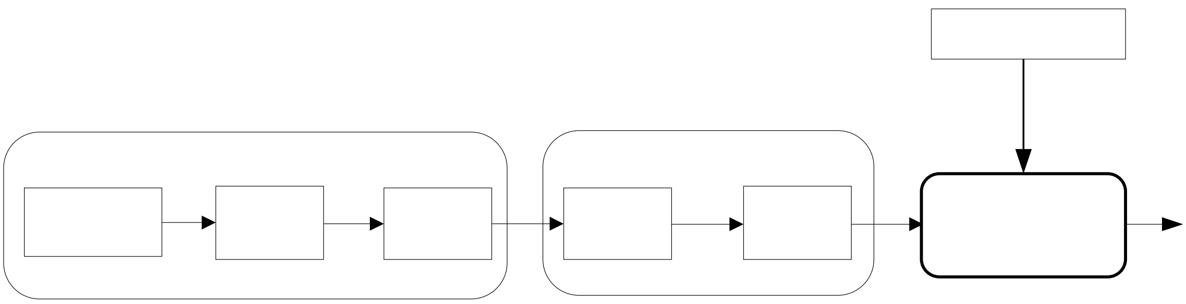
- Open loop control
- Close loop control

In some more elaborate HVAC plants, cascaded control [7] is applied where a separate controller determines the set-point of a secondary controller.

6.1 OPEN LOOP CONTROL

In this case the action according to the output signal of the controller does not modify the value of the measured parameter:

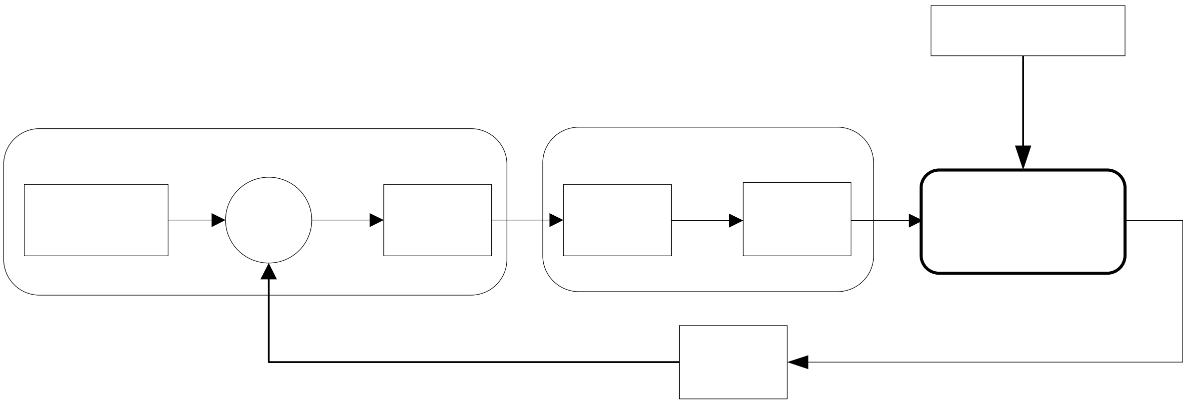
- climatic data : outdoor temperature and humidity, wind speed, …
- indoor events : windows opening, switch on/off, …



This kind of control is robust if and only if it is well defined at the design phase and provided that sizing and implementation of the system are properly done following design guidelines. It highly influenced by the design and sizing of the complete system. It can hardly take into account unpredicted perturbations.

6.2 CLOSE LOOP CONTROL

In this case the action according to the output signal of the controller will have a direct impact on the value of the measured parameter: The controller requires a set-point for the variable to be controlled.



The close loop control can use either feedback control or feed forward control with compensation. In the case of the closed loop control, the stability is a major issue. The control strategy should ensure what kind of information is obtained from the controlled system. The quality of the return signal is very important.

For example, if a command is sent to a motorised damper, what kind of information is sent back to the controller:

- no direct information
- an "electronic" value of the position of the damper, that is the actuator acknowledges receipt of a command but does not confirm that the damper has taken the desired position
- the actual measurement of the position of the damper

Following the type of feedback, there is a possibility to include a reset position of actuators after a regular interval of time.

Control

Setpoint

Sh

7 SENSORS

A sensor generally converts a physical property or quantity into a conveniently measurable signal or effect.

The specification of a sensor includes as listed by Underwood [8] in HVAC Control systems:

- Performance factors:
- Practical and economic considerations

Performance factors are: range, accuracy, repeatability, sensitivity, drift, linearity, response time

Practical and economic considerations include cost, maintenance (foir example re-calibration), compatibility (compatibility and interchangeability with other components and standards), environment (harsh environment…) and interference (sensitivity to ambient noise, such as radio frequencies…)

7.1 TEMPERATURE SENSORS

The most common sensors are resistance (positive or negative temperature coefficient) temperature detectors, thermistors and thermocouples

They are accurate and stable with a good response time. The thermistor is highly sensitive when compared to the RTD. The thermocouples are generally used in high temperature measurements (eg combustion chambers) since they are robust but are not very sensitive.

More recent development is integrated-circuit temperature sensors. They are semi-conductor diode junctions which display a linear current-voltage characteristic with temperature. They are inexpensive but fragile and range-limited. They are suitable for relatively low temperature measurements (room and in-duct temperatures).

Sensors based on material expansion are not studied.

7.2 HUMIDITY SENSORS

Dew point hygrometers and wet and dry bulb psychrometers are not described here (to be ratified by IC's)

Capacity hygrometers and dimensional change hygrometer measure the relative humidity.

7.2.1 Capacitive hygrometer

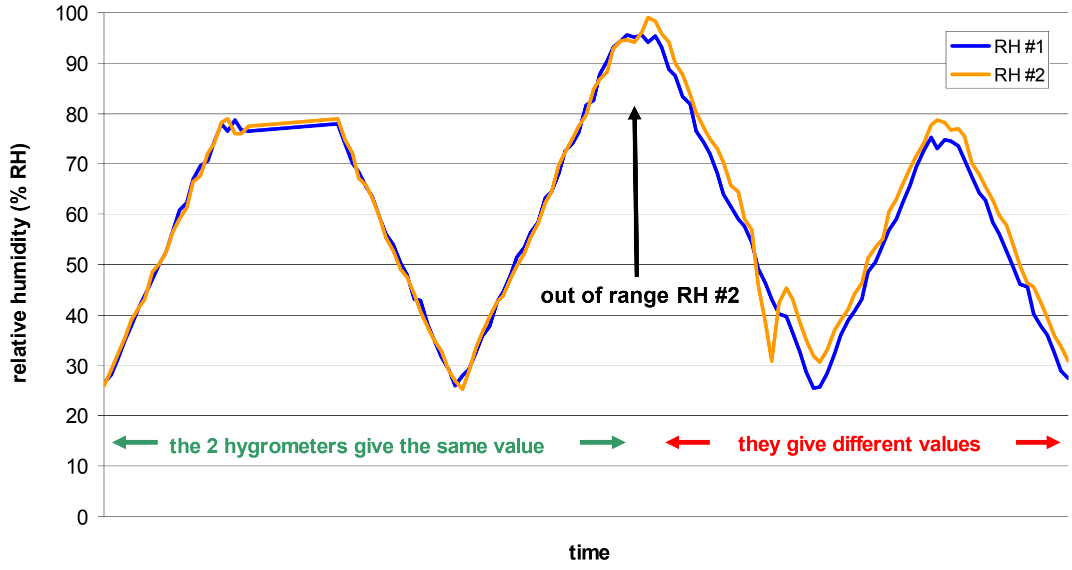
Advantages:

- accuracy,
- stability (if used in the good humidity range)
- low hysteresis (is used in the good humidity range)

Inconveniences:

- expensive ? (from 100 to 1000 €, depending on the humidity range)
- the humidity range can be limited (problems can occur if they are used outdoor, or in wet rooms).

<u>Note about humidity range of capacitive hygrometers</u> : The chart hereafter gives the output signal of two capacitive hygrometers in the same climatic enclosure ; the two apparatus give the same value until the apparatus #2 become out of range.



7.2.2 Dimensional change hygrometer

This kind of hygrometer is based on the increase on the length of a tape (hair but also cloth) versus the relative humidity.

Advantages:

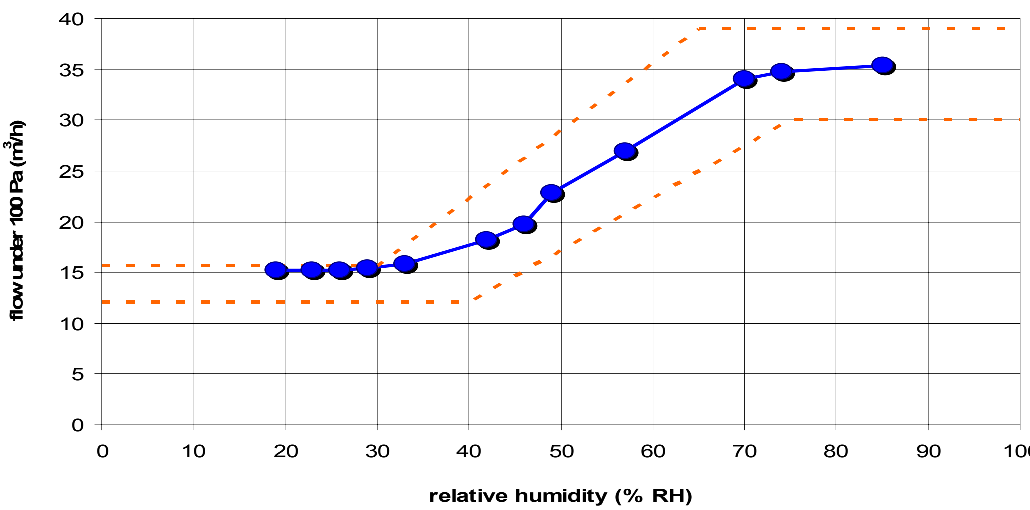
- simple,
- inexpensive
- long term stability (see note)

Inconveniences:

- long response time
- hysteresis

Long term stability : some authors indicate that these products have a poor long term stability inducing frequent recalibration.

Note about long term stability of dimensional change hygrometers : We give hereafter measurement made on a hygrothermal extract grille (sensor made with a tape of cloth) after 8 years of running without any recalibration. In blue the measured points, in orange dotted the specifications (with her tolerance)



7.3 AIR (OR WIND) SPEED

Hot wire or hot film anemometers are not described here due to their dust sensitivity. Ultrasonic anemometers are too expensive for consideration in ventilation control systems

Cup or propeller anemometers are well adapted to wind and airflows in duct measurements.

Advantages:

- accuracy,
- stability
- low hysteresis

Inconveniences:

- relatively expensive (≈ 150 €)
- propeller anemometers have to be cleaned every 3 to 6 month (depending on ambient dust).

7.4 INFRARED PRESENCE SENSOR

These sensors detect the presence of occupant by measuring their movements.

Advantages:

- low cost (≈ 50 €)
- easy to use (signal yes/no)
- accurate

Inconveniences:

- some "activities" are made without movement :watching television (except during football matches), sleep (even restlessly sleep),
- sensitivity to the position (dead zone)

7.5 CO_2 SENSORS

There are several types of CO_2 sensors [9]. In practical application where the CO_2 sensor is required for control of air flows over a long period of time, photometric infrared detector are mainly used.

Advantages:

- accuracy,
- stability,
- linearity
- low hysteresis

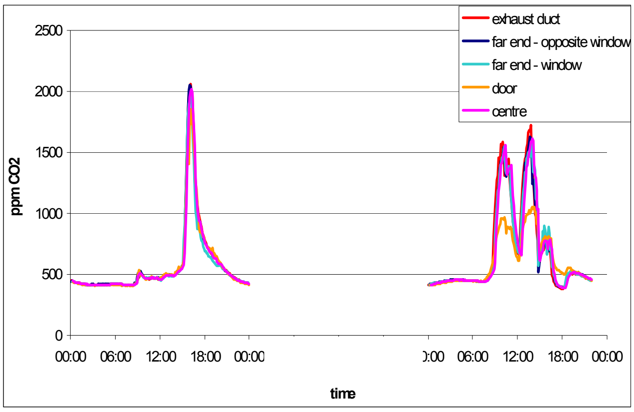
Inconveniences:

- expensive (from 200 to 700 €)
- long response time (but compatible with ventilation control)

Note about stability of CO_2 sensors : CO_2 concentration has been continuously monitored in a meeting room in five points :

- *in the extract duct (behind one outlet),*
- *near the window in the far end of the meeting room*
- *in the far end of the meeting room opposite the window*
- *near the door*
- *at the centre of the room*

The graph hereafter follows the concentration in CO_2 for two days:

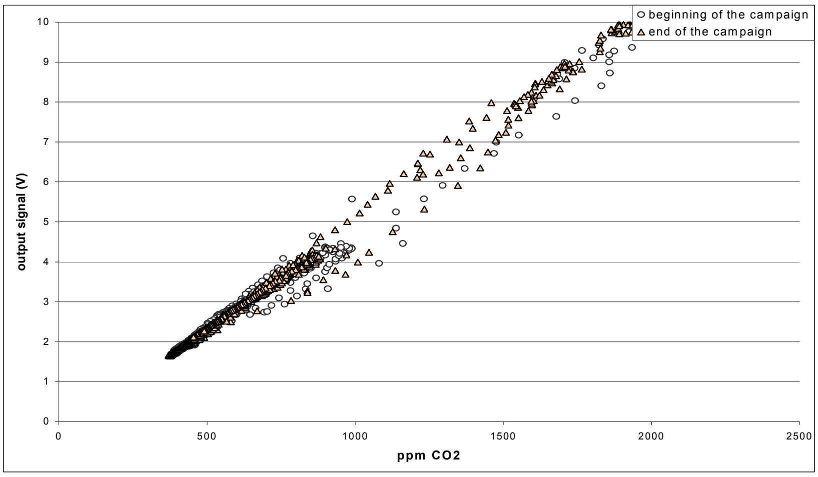


The first day we can notice that all the curves overlap: there is thus no CO_2 concentration gradient in the meeting room. The second day, the CO_2 concentration near the door is lower than the concentration in the other points of the room because the door has remained half-opened. In both cases, and although the window is not airtight we don't notice dispersal for the point of measure situated near this one.

It allows that there are only few constraints on the position of the sensor in the room as far as is avoided the zones of fresh air :

- *nearness the windows,*
- *nearness the internal doors,*
- *nearness the inlets,*

Note about log term stability of CO_2 sensors *The graphs below show for one CO_2 sensor the output signal (in Volt) according to the CO_2 concentration (ppm) measured in the extract duct in the beginning of the measurements campaign (April 2002) and at their end (November 2002).*



We can note that, in eight months, there was no drift in the time of the response of the sensors.

7.6 MULTIGAS SENSORS (VOC SENSORS, MIXED GAS SENSORS)

These sensors are sensitive to odours, tobacco smoke, building emission, but also to temperature, air humidity. The sensing element consists of a metal oxide surface which is heated. It consists of either a single sensing element which is able to detect the presence or concentration of several gasses or an array of sensing elements. In the latter case, electrochemical sensors selective to one gas only.

Advantages:

- inexpensive,
- little maintenance

Inconveniences:

- poor accuracy
- long response time
- difficult and sometimes impossible to calibrate

It seems difficult to use the absolute value of the output signal since it is difficult to say what it represents. It is probably possible to use a relative value (derivative).

7.7 PRESSURE SENSORS

This kind of sensor is generally used to control flow in ventilation systems. It is more often used to give Boolean information that is either the flow rate is above or below a predefined value. They can also be used to make actual flow measurement in the ventilation system.

Sensors include:

- Capacitive – low sensitivity and restricted to low pressure applications such as ventilation filter differential pressure measurement and VAV system fan control
- Inductive – based on linear voltage differential transformer. They are compact and suitable for low pressure applications of ventilation systems
- Strain gauges – based on the change in electrical resistance of a body as it deforms under pressure → suitable for high pressure applications. Little use in HVAC system.
- Piezoelectric - sensitive and can cope with rapidly fluctuating conditions and a wide pressure range.

7.8 WIND DIRECTION SENSOR

It is easily obtained from one on-site weather station or from façade sensors depending on the complexity of the control strategy.

7.9 POSITIONING OF SENSORS

Positioning of the sensors is an issue that must not be neglected. For example, to have a relevant indication of thermal comfort level, the temperature and humidity level, should be measured at the centre of the room. This is hardly possible in practice in an occupied space.

Since the sensor will send the information that will be decisive in the control loop, a wrong positioning of the sensor will induce a permanent error or deviation in the control signal.

Where to place temperature sensors, CO_2 sensors, pressure sensors, humidity sensors?

Temperature sensors for indoor air should not be placed in drafts (induced by ventilation, heating or cooling systems) or exposed to excessive radiation, for example solar radiation.

It is observed that CO_2 sensors are less sensitive to position than temperature sensors since there is a rather uniform distribution of CO_2 concentration on the time scale used in the control strategy based on CO_2. This is true for rooms ventilated by dilution. The sensor should be placed within the occupied zone. It is obvious that the sensor should not be placed near a window or door.

Similarly care should be taken when positioning pressure sensors in ducts to avoid being in turbulent regions of the flow.

Examples of sensors are provided in appendices A and C on a predefined description card.

8 ACTUATORS

Except for supply air pre-heating or humidification, and use of controllable heat exchangers, the actuators can be always expressed as a modification of the pressure flow characteristics of a given component.

8.1 DAMPER ACTUATOR

They are either electric or pneumatic. The choice depends primarily on cost and availability. The main advantage of a pneumatic actuator is the speed of response. Interfacing of pneumatic actuators to electronic sensors and BACS can be achieved at reasonable cost. The main interest of an electric actuator is in general a lower cost.

8.2 FAN MOTORS

They can be on-off type, stepwise or variable speed.

8.3 WINDOW ACTUATORS

There are 3 main types:

- electric chain actuator,
- spindle actuator,
- and electric linear or piston actuator

Examples of actuators are provided in appendices B and C on a predefined description card.

PART 3

IMPLEMENTATION OF HYBRID VENTILATION CONTROL STRATEGIES

1 INTRODUCTION

The description of more and more complex hybrid ventilation control strategies imply more and more interactions and data exchange between sensors, actuators, "decision units", controllers for the whole building. This is a general trend in HVAC industry and the building automation system offer two main possibilities to integrate the control of different equipment/applications in a building:

- Proprietary systems. A proprietary system is a closed system that is developed by a single manufacturer/contractor.
- Open systems. An open system is one where in standards are developed, published and maintained by an independent recognised organisation (CEN, ASHRAE/ANSI…).

Although open communication protocols are now becoming used for the integration of equipment from different manufacturers, there is a tendency to adopt proprietary systems for the development of hybrid control strategies in residential building, especially single family houses due to the size of the system involved. Further description of communication protocols are provided in appendix D.

It is therefore important to have a clear view of the building automation architecture and the functional scheme of the chosen control strategies for its implementation.

This part deals with the following issues:

- Building automation architecture
- Definition of a functional scheme of a control strategy
- Examples of hybrid ventilation control strategies

2 BUILDING AUTOMATION ARCHITECTURE

The definition of building automation architecture follows the works carried out in the CEN TC 247 and ISO TC 205 to propose a standard at ISO level on Building Automation and Control Systems [10].

A Building Automation and Control System mainly consists of

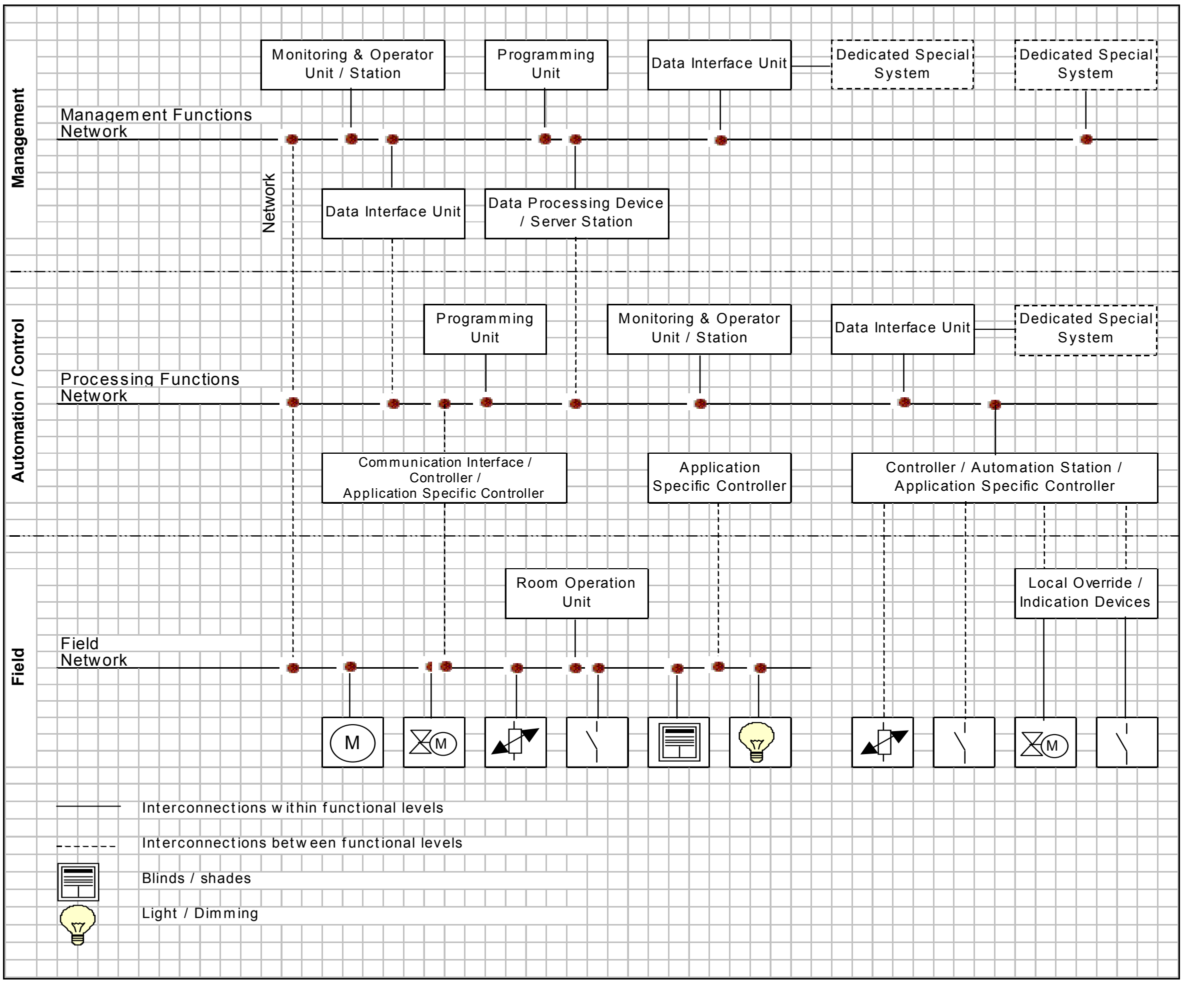
- Hardware (field and control devices, cabling, communication and computing devices),
- Functions (performed by software) and
- Services (achieved by engineering).

There are three functional levels in a building automation hierarchy:

- Management level: top level of the architecture for supervision, data processing and archiving, energy management…
- Automation/control level: intermediate level for closed loop control, optimization monitoring, interlocks of building services performed in real-time within self contained controllers [automation stations].

- Field level: bottom level to perform the connection to the physical items of plant providing the necessary information about the conditions, states and values of the processes (sensors, actuators, switches…).

The following diagram [10] shows the data communication among the 3 functional levels.



This architecture is applied to the development of the control strategy for hybrid ventilation. It is to be noted that this architecture does not need to be used completely, and depends on the complexity of the control strategy. In some cases, the management level might not be used.

The implementation of the functional levels will depend on the type of products available and also commercial strategies of different manufacturers. At this point two main architectures may be distinguish

- so-called "centralised" and
- "decentralised" systems.

In the centralised systems **most of the functions** are integrated in products which ensure also supervisory control (management level).

In decentralised systems, the functions are brought down as far as possible to the field level. In this case there is extensive use of "smart" sensors and actuators. These, instead of ensuring only the connection with physical processes, are able to integrate a certain level of logic, data processing capabilities, filtering of measured signals...

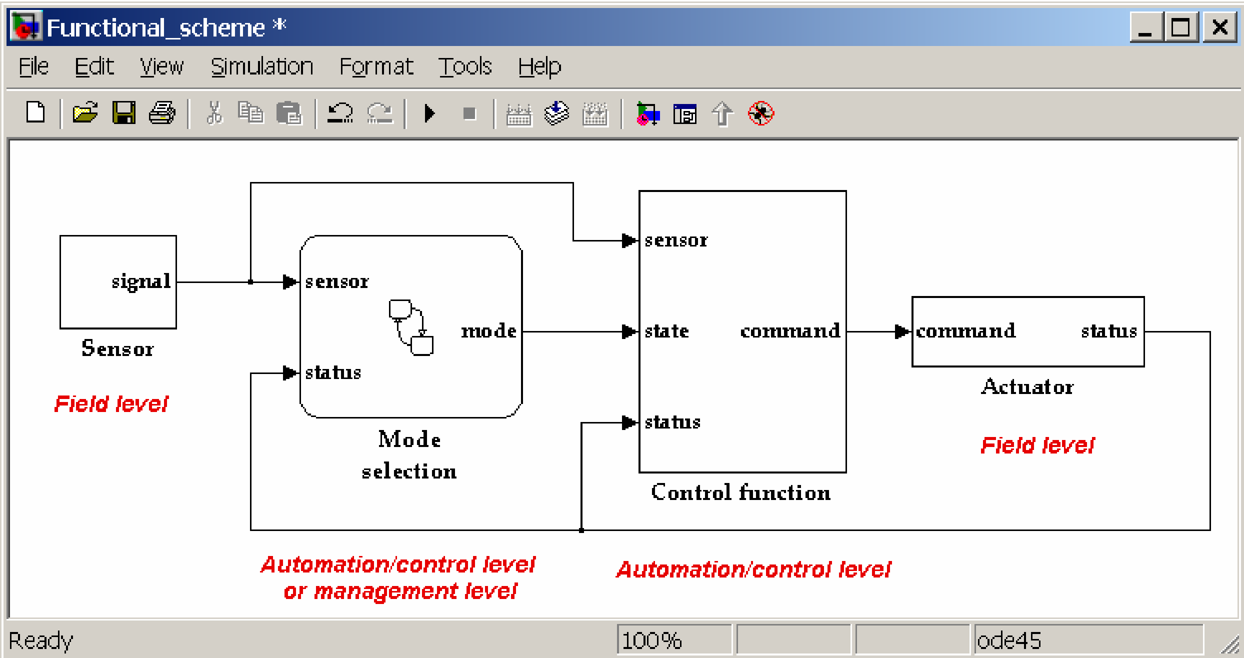
The choice of the architecture has also an influence on the type of data communication that will be used. In one hand, if all the "intelligent functions" are integrated at the management level, the signal sent to an actuator (field device) might be the exact position to be taken by the actuator. On the other hand, when the "intelligent functions are distributed toward the field devices, the management level might send only a set point shift to the automation level.

3 DEFINITION OF A FUNCTIONAL SCHEME FOR A CONTROL STRATEGY

The definition of a control strategy for hybrid ventilation can be divided into three parts:

- Mode selection units
- Control function units
- Field level units (actuators and sensors)

The following diagram shows the interactions between the different parts. Note that there may be several information witch are transferred from one block to another. Similarly a control strategy may involve several blocks.



The diagram also shows the link with the Control communication architecture defined in the proposed ISO standard.

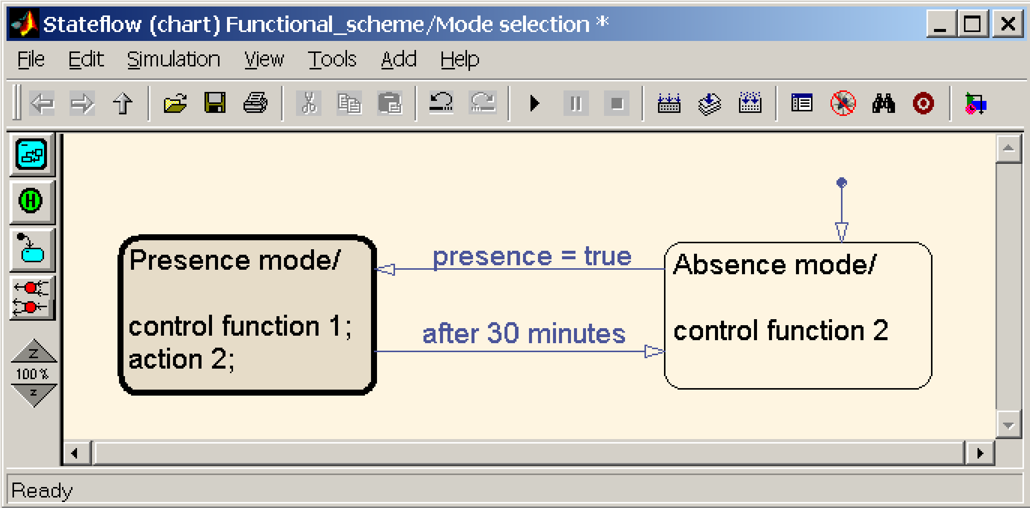
3.1 MODE SELECTION UNIT

The "Mode selection unit(s)" of the strategy can be view as the back-bone of the strategy. It gives all the functioning configurations that will be allowed by the system. It must be defined in an exhaustive way and allows for an overview of the control functions.

The mode selection unit is structured as:

- a list of modes or sub-modes (the structure may contain several layers)
- a list of transitions between modes / sub-modes

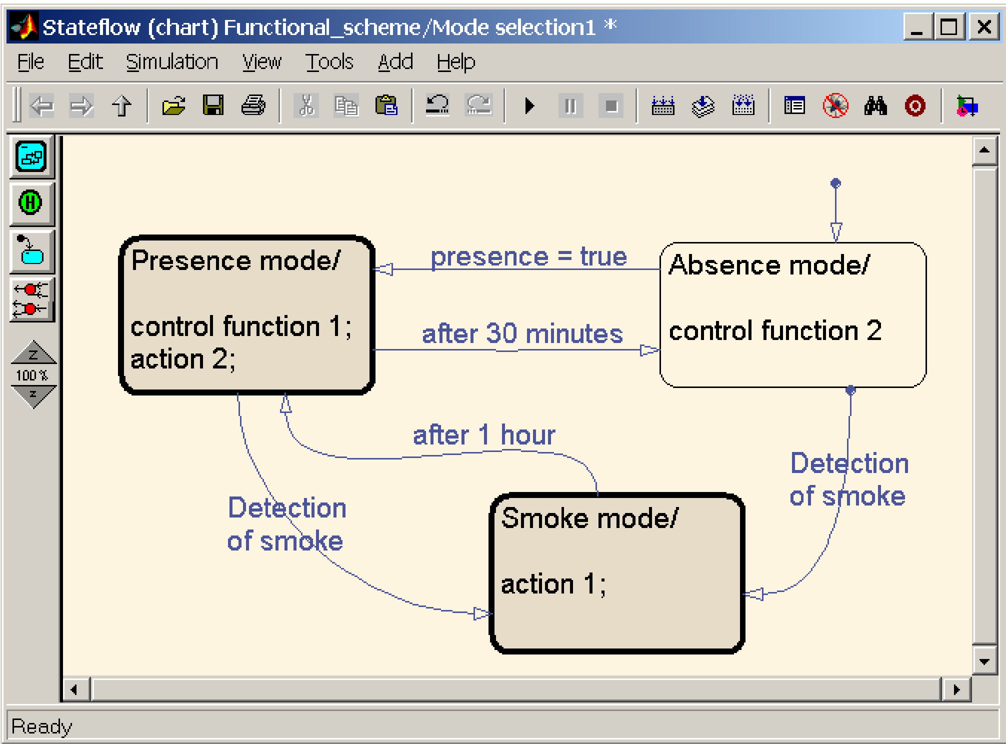
The figure below shows an example of modes description with specific transitions.



In this description structure, it is quite easy to add new modes since it will not be obvious at the very beginning of the definition of a strategy to be exhaustive.

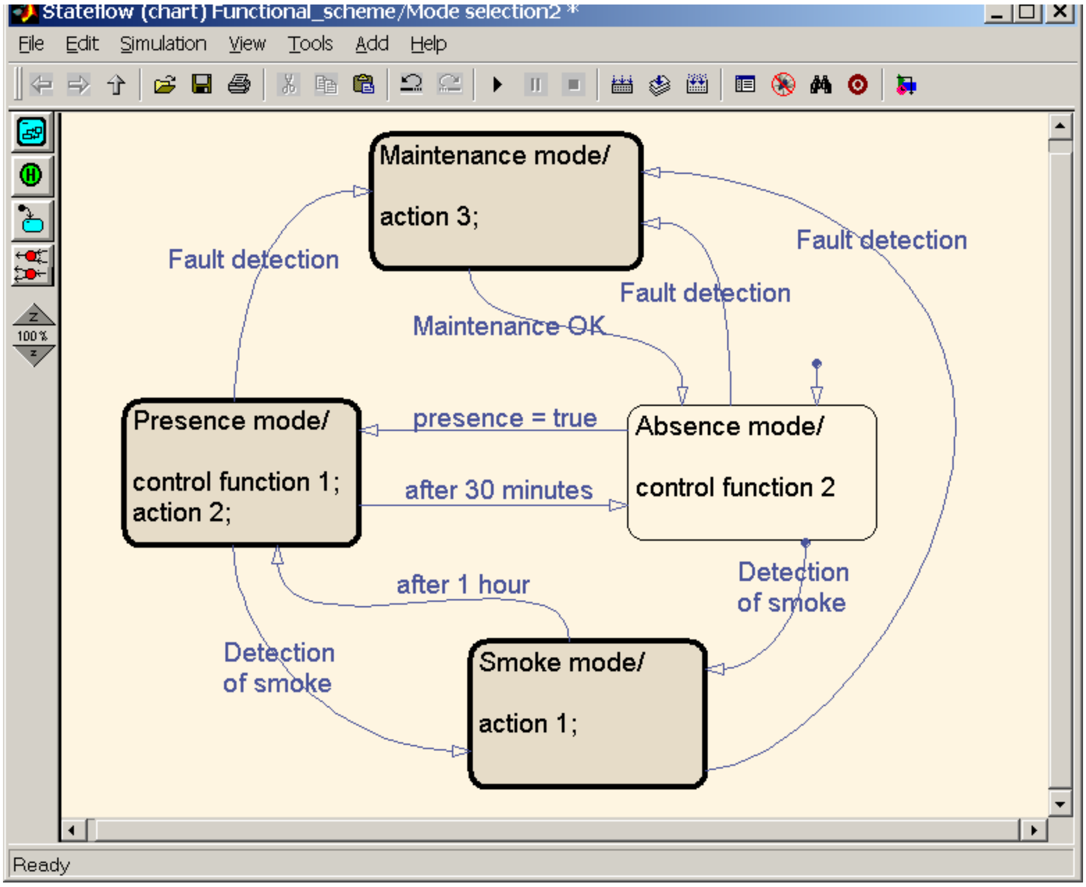
Furthermore, it ensures that transitions are defined for "entering" and "leaving" all modes. **In any such strategy there should be a starting point !** In the above case the strategy initial condition is in the "absence mode".

If the strategy has a specific behaviour in case of smoke detection, a new mode is added.



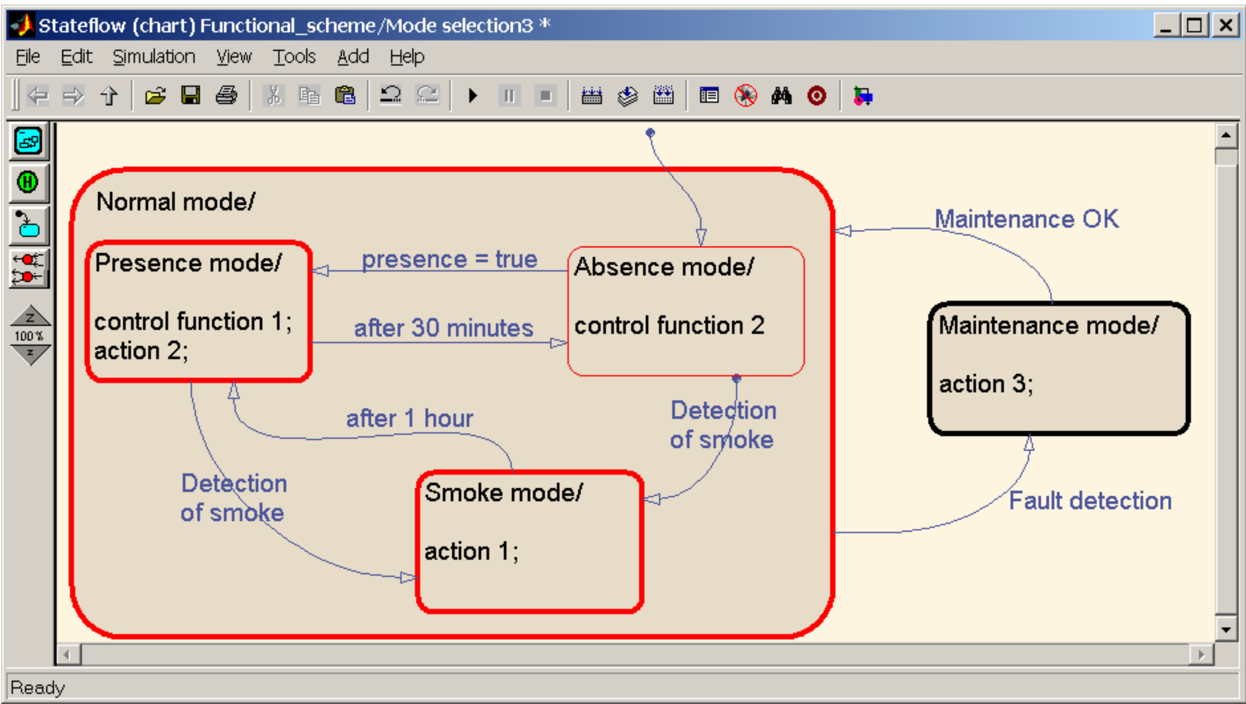
The above strategy is described in one layer. If for example, there is a need to define a maintenance mode, one can chose to remain in a single layer structure or define two layers depending on the complexity of the strategy.

Option 1 : including a maintenance mode in a one layer description



Care is taken to add also the appropriate transitions with the new mode.

Option 2: including a maintenance mode as an upper layer (creating sub-modes)



In this case, two main modes have been defined: normal mode and maintenance mode with specific transitions. The existing modes appear as sub-modes of the normal mode.

List of modes that can be used in hybrid ventilation control strategy

- Winter/summer/inter-season
- Night/day
- Occupied/unoccupied periods
- Presence/absence or level of specific pollutants (smoke, kitchen odours, toilets...)
- Presence/absence of excessive humidity level or exact measurement of humidity level (in kitchen, bathroom,...)
- Window/door status (open or closed)
- Normal/maintenance/security conditions

Definition of transitions:

- Use of presence signal
- Use of CO2 level
- Use of humidity level
- Use of temperature difference
- Use of pressure difference
- Use of manual interference (switch...)
- Use of time delays

The definition of control modes and transitions must prevent concurrent information sent to same control function and eventually to the same actuator

One key issue is the definition of transition from a manual mode to an automatic mode that is how to get back to the stand-alone functioning of the control strategy once there has been manual interference. In commercial, buildings, control strategies are usually reset to automatic mode in unoccupied periods. In residential building, this might be done once or twice a day.

3.2 CONTROL FUNCTION UNIT

In this part, the control laws that are applied in the strategy have to be implemented.

It is very common to use classical laws such as on/off type of control or PI control with carefully selected set points and dead bands to give the response required in a similar way as for heating and cooling control systems. Further reading on these control laws is available in [7].

Use of fuzzy logic over the whole range of the control parameter can also be an alternative. There are several attempts to use fuzzy logic [11], neural networks, genetic algorithms in control loops of HVAC systems in general but these remain on experimental basis. Genetic algorithm is a late comer in the building field. An application of genetic algorithms has been achieved on blind control with respect to user needs [12] which is an issue similar to the impact of human behaviour on ventilation control strategies.

Adaptive control may also be investigated. In adaptive control, the controller adapts the system changes and adjusts settings automatically so that acceptable system control is sustained. In some cases the system may include the occupant behaviour which is taken into consideration in the auto-learning process. An example of adaptive control is optimal start stop for heating/cooling systems.

Predictive control does not seem to be of prime importance in the definition of control algorithms for hybrid ventilation in residential buildings. This is no clearly identified parameters for use of predictive control principles.

3.2.1 Particular case of window opening

The control authority of a window is slow and non-linear or proportional, thus the use of sophisticated control algorithms will not bring greater accuracy.

Given the pulsing effect of wind or natural ventilation, avoid using automatic control which continuously tries to correct the controlled variable

- PI and PID might not be appropriate
- use large dead bands to allow for normal swing of daily temperature

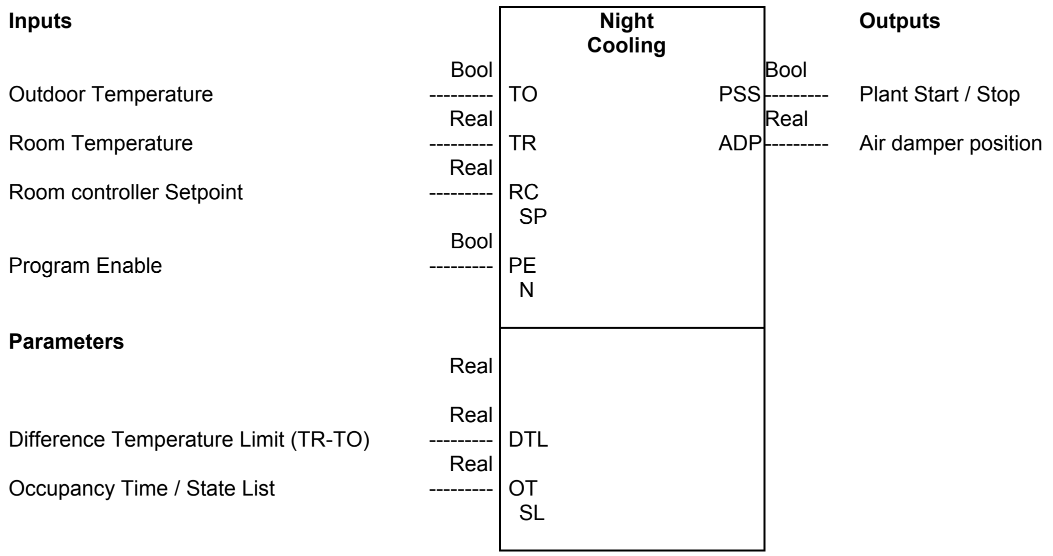
3.2.2 Example of function unit description (excerpts from the ISO standard)

Night Cooling

The Night Cooling function provides a logic output when an algorithm calculates that the inside temperature is above a temperature that will be required within the forthcoming occupancy period. Other considerations will be the outside temperature during the night.
The BACS Information List shall indicate this function per output address.

Performance criteria: None

Function Block example:



Function Block example abbreviations

NAME	TYPE	DESCRIPTION	UNIT
INPUTS			
TO	REAL	Outdoor temperature	°C
TR	REAL	Room temperature	°C
RCSP	REAL	Room controller Setpoint	°C
PEN	BOOL	Program enable	
OUTPUTS			
PSS	BOOL	Night Cooling output state (Plant Start / Stop)	0 / 1
ADP	REAL	Air damper position	%
PARAMETERS			
DTL	REAL	Difference temperature limit (TR-TO)	K
OTSL	REAL	Occupancy time / state list	

This function operates during the cooling season to provide "free cooling". It makes use of relatively cooler air in the early morning to cool down the buildings internal fabric and inside air. Ventilation is started with outside air dampers fully open if, and as long as, outside air is significantly cooler than inside air and inside air temperature is significantly higher than occupancy set point.

Optimum Start / Stop

The Optimum Start / Stop function provides a logic output when an algorithm calculates an optimum time to switch on or off an item of plant so as to optimize the energy usage, based on the input of the Time Schedule function.

Performance criteria: None

Function Block example:

Inputs	Type	Optimum Start Stop		Type	Outputs
Outdoor Temperature	Real ---------	TO	PSS	Bool ---------	Plant Start / Stop
Room Temperature	Real ---------	TR	CPC	Bool ---------	Current program Condition
Actual Time	Real ---------	AT			
Program Enable	Bool ---------	PEN			
Parameters	Real				
Occupancy Time schedule	Real ---------	OTS			
Basic Parameters	Real ---------	BPAR			

Function Block example abbreviations

NAME	TYPE	DESCRIPTION	UNIT
INPUTS			
TO	REAL	Outdoor temperature	°C
TR	REAL	Room temperature	°C
AT	REAL	Actual time	HH:MM
PEN	BOOL	Program enable	
OUTPUTS			
PSS	BOOL	Optimum Start / Stop. Output state (Plant Start/Stop)	
CPC	BOOL	Actual Optimum Start / Stop state information	
PARAMETERS			
OTS	REAL	Occupancy time schedule	
BPAR	REAL	Basic parameters	

The optimal start function calculates the best possible starting time for the change to occupied from unoccupied mode on the basis of the controlled temperature (e.g. room temperature). To achieve the desired conditions at the start of occupancy it can also be necessary to consider outside conditions, supply capacity of energy source and the thermal behaviour of the building.
The optimal stop function calculates the earliest stop time for the change to unoccupied from occupied mode normally on the basis of outside conditions. It is also necessary to consider the thermal behaviour of the building in order to maintain the desired conditions until the termination of occupancy.
This function may be with fixed parameters or a "self adaptive" function.

3.3 FIELD LEVEL UNITS

The Field level units serve for the description of the characteristics of sensors and actuators. Note that local overrides are also defined at this stage.

3.4 IMPLEMENTATION OF FUNCTIONAL SCHEME

The functional scheme can be implemented in different ways in products following the objectives (marketing, financial…) of «players» involved in the development of the product.

ISO standard notations	Components of ventilation system	Solution 1	Solution 2	Solution 3	Solution N
Field level **Or** Field level & Automation / control level	Inlets, supply fans…	Actuator	Actuator Control function Sensor	Actuator	…
Management level & Automation / control level **Or** Only Automation / control level	Control or management device (electronic component)	Mode selection Control function Sensor	Mode selection		…
Field level **Or** Field level & Automation / control level	Outlets / extractors	Actuator	Actuator Control function Sensor	Actuator Mode selection Control function Sensor	…

4 EXAMPLES OF HYBRID VENTILATION CONTROL STRATEGIES

4.1 FRENCH HYBRID VENTILATION SYSTEM

It uses a very simple principle. Outdoor air enters in habitable rooms and is extracted in service rooms.

It consists of:

- self regulated inlets,
- self regulated outlets
- a motorized cowl

The motorised cowl is used at specific time. It is turned on high speed during cooking time (eg. 11h00 to 13h00 and 18h00 to 20h00). It switches on normal speed if outdoor temperature is higher than 10 °C

There is no manual action on the system. Change of fan speed is achieved by a time schedule

The control parameters are:

- outdoor temperature
- motor speed shift (normal/high) following a threshold value or schedule

This system is mainly used to refurbish existing buildings with collective ducts.

<u>Characteristics of the cowl</u>

- Motor off

  Pressure losses ζ = 1.22

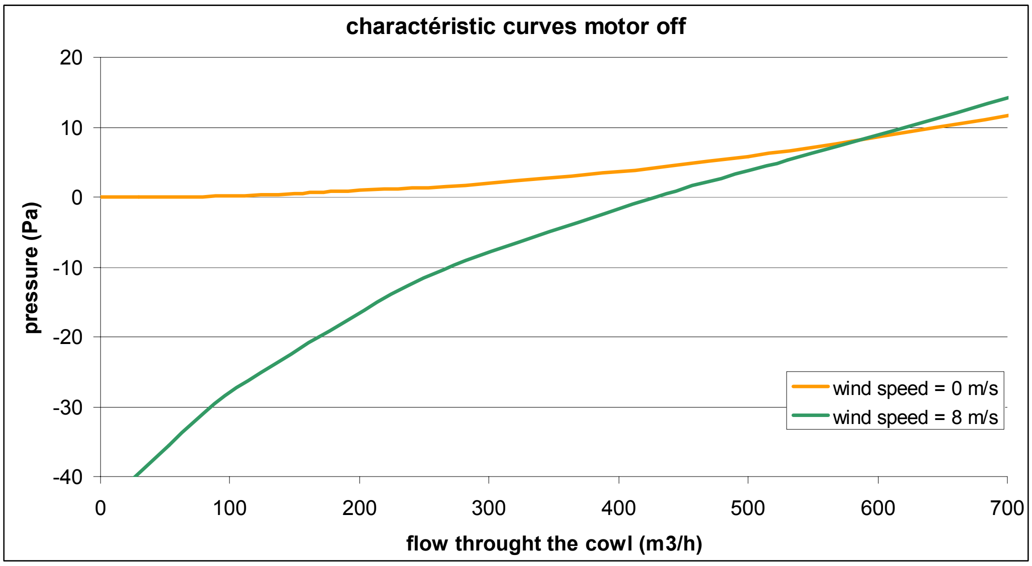
  Suction effect C = -0.7 (average without flow),

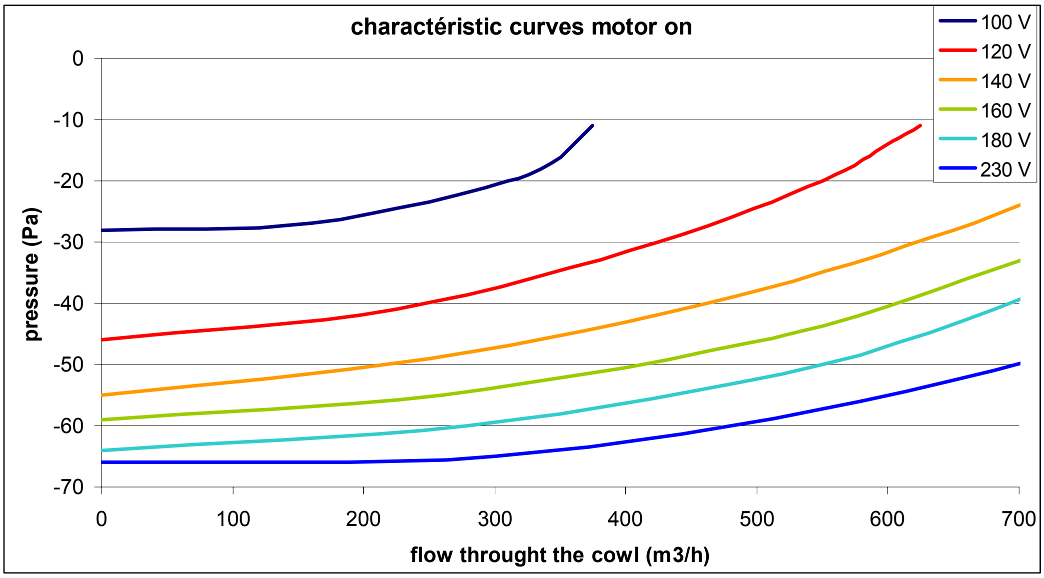
  C = -0.2 (average with flow),

- Motor on

  High speed 60 Pa / 500 m3/h

  Normal speed 25 Pa / 250 m3/h





4.2 PORTUGUESE HYBRID VENTILATION SYSTEM

The principle is similar to the French hybrid ventilation system, that is, air inlets are located in the habitable rooms while air outlets are placed in the wet rooms. The main different on the system is the use of 2 exhaust fans (one for the ducts linked to the kitchen and one for the duct linked to the bathroom and toilets) instead of motorised cowls.

In this hybrid ventilation system, the control strategy favours the use of natural ventilation and it switches the fans only if the exhaust air flow rate is lower than a pre-defined value. In this aspect it differs from the French one which uses a pre-defined time schedule.

Further details on this hybrid ventilation system are available in the WP6 report on the study of the Portuguese ventilation system (chapter 5).

4.3 DESCRIPTION OF GENERIC HYBRID VENTILATION SYSTEMS WITH LOCAL CONTROL STRATEGIES

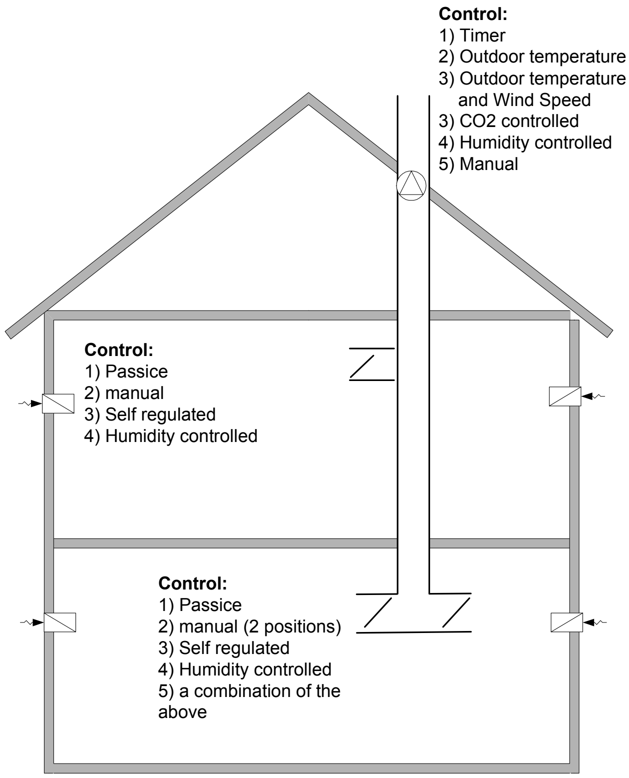
(to be completed !!!!!!!)

The preceding 2 paragraphs are examples of existing hybrid ventilation systems. In this part, the ideas of hybrid ventilation systems with local control are provided in a generic way with different options on air inlets, air outlets and fans suitable for low pressure systems.

The main components in such a system in particular, extract ventilation type are:

- Air inlets
- Air outlets
- One or more fans

In case of balanced ventilation systems, a heat exchanger may be included in the system.



The fan is

- working on a time scheduler as in the case of the French hybrid system (kitchen for detached house or collective ventilation system in residential buildings)
- driven by a manual control to switch on and a timer fro switch off
- controlled with respect to outdoor temperature
- controlled with respect to outdoor temperature and wind speed (where the control on wind speed serves to maintain a base ventilation)
- driven by CO_2 control (measured in exhaust duct)
- geared by a humidity control

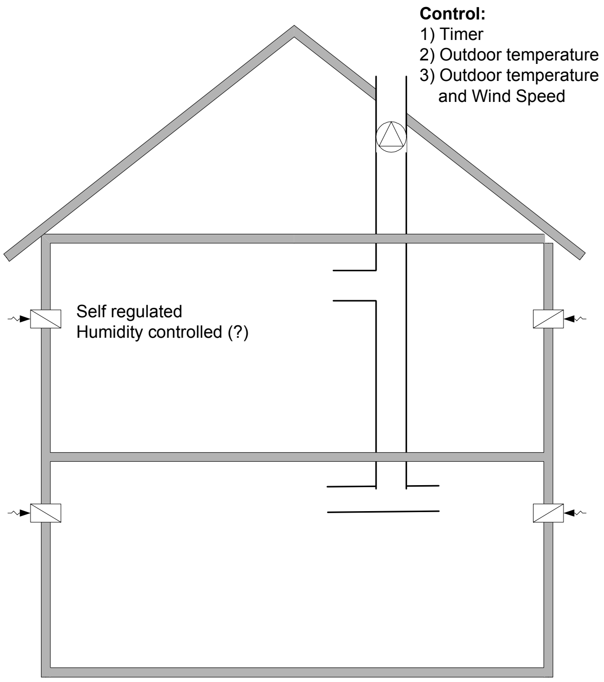
The air outlet may be:

- passive
- manual (having 2 positions)
- self-regulated
- humidity controlled
- or a combination of these such as humidity control and "2positions".

Similarly the air inlets can be inlets

- passive
- manual (a few positions)
- self regulated
- humidity controlled

Example of with self-regulated inlet, passive outlet, and a fan



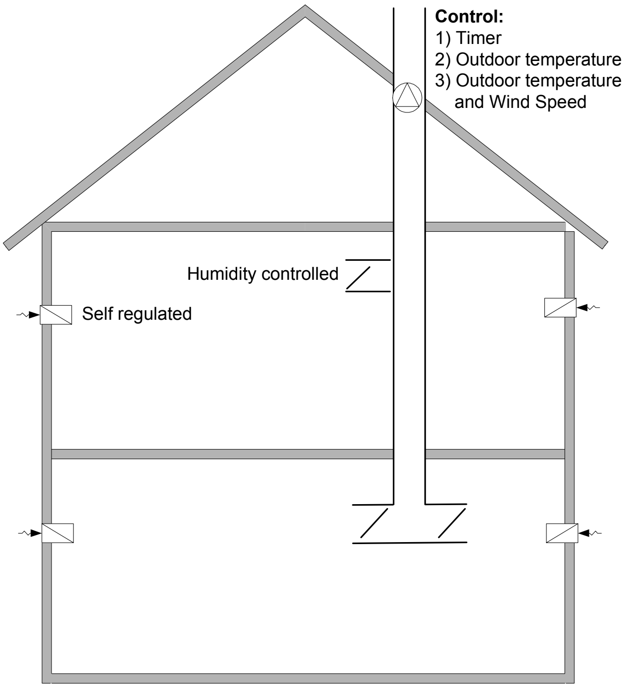
These systems are very simple but it is difficult to have a good balance between quality and energy optimisation. The ventilation system is greatly influenced by the air tightness of the building.

Self regulated inlets, humidity controlled outlets and exhaust fan

The fan is either

- working on a time as in the case of the French hybrid system
- controlled with respect to outdoor temperature
- controlled with respect to outdoor temperature and wind speed

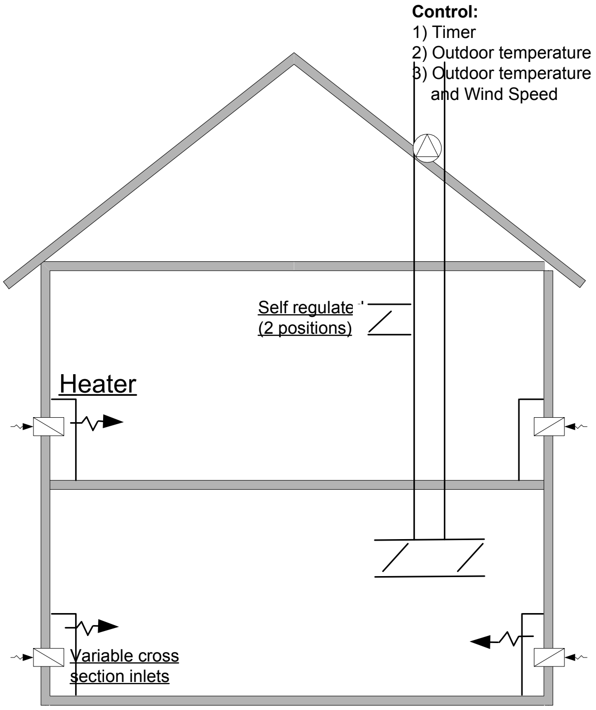
The inlets are self regulated. The outlets are humidity-controlled.



These systems are also simple. They offer better air quality that the previous system. However, with humidity controlled outlets, there might be risks of high CO_2 concentration.

The system is modified for cold climates as follows:

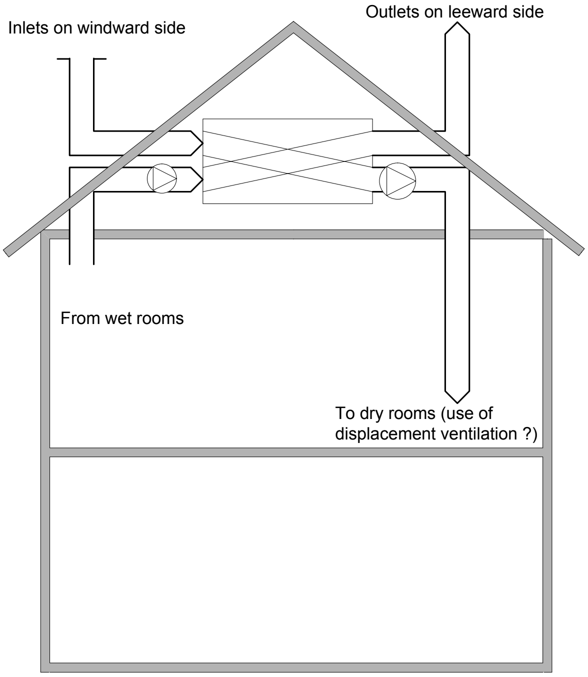
The inlets have variable cross section and the air is pre-heated. The outlets are self regulated and have 2 positions.



Problem of backdrafts are also common in these systems.

Balanced hybrid ventilation system

Taken from work with ICs.



In the system, the inlets are carefully set on the windward side while the outlets are on the leeward side.

The fans are either driven by humidity sensors or CO_2 sensors.

4.4 DESCRIPTION OF NEW HYBRID VENTILATION SYETMS WITH CENTRALISED CONTROL STRATEGIES

This part is based on the work carried out with the ICs and on an ongoing doctoral thesis [13].

Two ventilation control strategies described for a single family dwelling with two floors (see Figure 3) is simulated. The dwelling is heated by a hot water radiator system and ventilated by a mechanical exhaust system with natural supply inlets (see Figure 4).

The ventilation system includes a low pressure fan. The air inlets and extract grilles are controlled with 8 positions and the fan has 3 speed levels. The level 0 means that the fan is switched off. Pollutants generation and water vapour production are based on the IEA Annex 27 scenario [4].

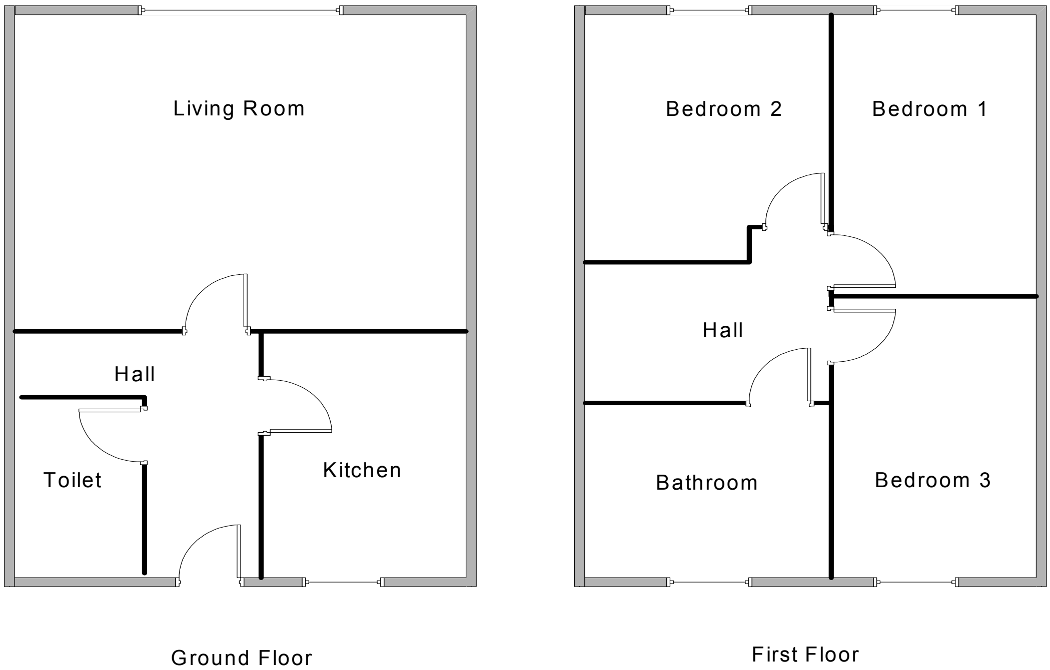


Figure 3. Single Family Dwelling

4.4.1 Overview of control strategies

The control strategies are centralised ones, that is, all the "intelligent" control functions are placed in one central unit. The communication with between the central unit, sensors and actuators

The first ventilation control strategy, called HV1, is based on:

(1) Presence detectors in the bedrooms and the Toilet;

(2) Movement or Agitation detector in the living room;

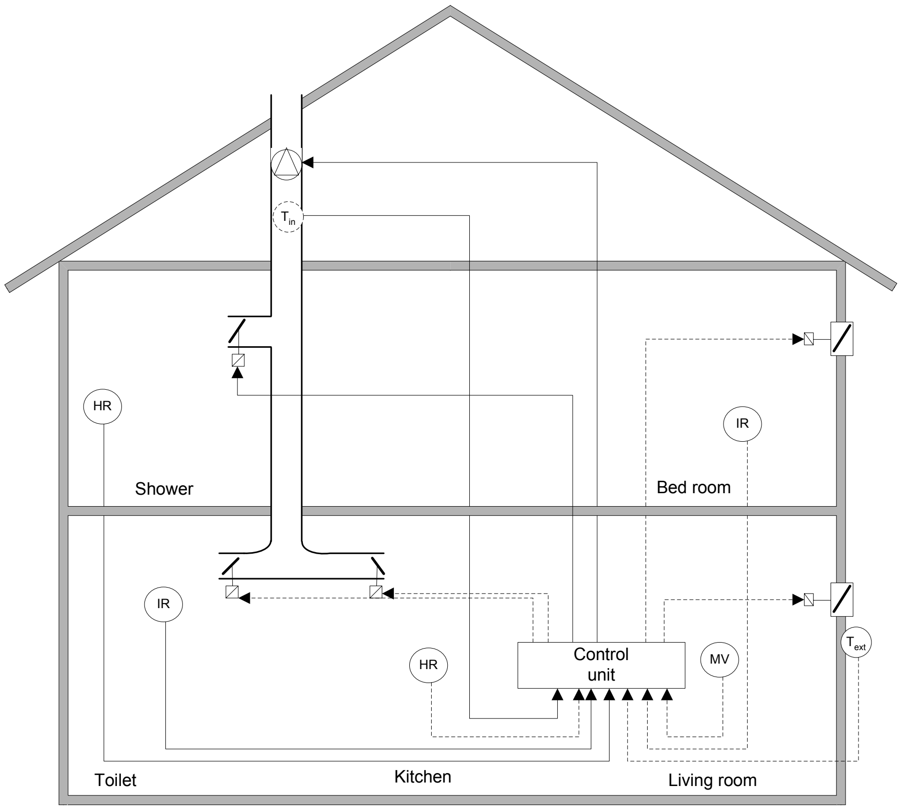
(3) Relative humidity sensors in the wet rooms.

Every 10 minutes, the control algorithm HV1:

- defines a target airflow based on sensor detection
- defines the total target airflow which is the maximum of the target fresh air and the target extracted airflow (minimum target airflow is 40 m^3/h)
- calculates the fan speed level based on the comparison between the stack effect available (depending on the difference between indoor and outdoor temperatures) and the pressure

loss through the whole ventilation system using an analytical solution of a network of airflow components

- computes a new target airflow per room in the case where there is a difference between the target fresh airflow and the target extracted airflow to balance the fresh and the extract airflow
- calculate the positions of the inlets and extract grilles



The second ventilation control strategy, called HV2, is based on:

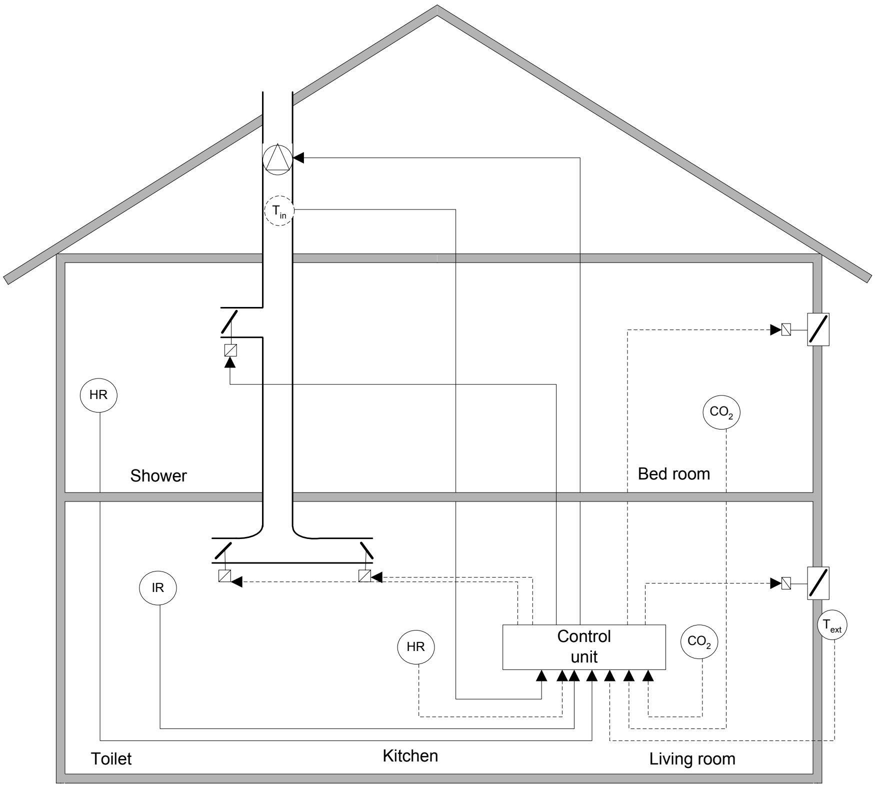
(1) Presence detector in the Toilet;

(2) CO_2 sensors in the living room and bedrooms;

(3) Relative humidity sensors in the wet rooms.

In the control algorithm HV2, every 10 minutes:

- Inlets open based on CO_2 level in the dry rooms and maximum Relative Humidity level RHmax in the wet rooms. The minimum position is based on the outdoor temperature
- Extract grilles open based on RH level in the wet rooms and the maximum CO_2 level in the dry rooms CO_2max. The minimum position is based on the outdoor temperature
- Fan speed starts to increase when CO2max > 900 ppm or RHmax > 60%. Fan speed reach its highest level when CO_2max >1200 ppm. In the other case, the fan is switched off when the outdoor temperature is less than 10°C.



For both strategies, the control of heating radiators is made by thermostatic valves and the set point temperature is 20°C.

4.4.2 Evaluation of control strategies

The evaluation of ventilation control strategies is made with respect to:

(1) indoor air quality criteria (Indoor CO_2 concentrations less than 1050 ppm [14]),

(2) thermal comfort (in winter, operative temperature should be close to 22°C ±2°C [1]),

(3) energy consumptions criteria,

(4) control criteria (actuators movements).

The evaluation was carried out by implementing the control strategies in the SIMBAD simulation tool [15].The simulation has been performed for a period of 3 months (from January 1st) for Trappes climate (France). The simulation time step is one minute. The control strategies are implemented in the Stateflow environment [16] which is dedicated to the description of finite state machines and the modelling of complex logic and state diagram in the Simulink [17] graphical environment. The implementation of such sequential logic is straight forward in this environment and it enables direct visualisation of states during the simulation.

Figure 6 shows that HV1 mainly controls grilles whileHV2 acts primarily on the fan speed. This is due to the fact that the control algorithm of fan speed for HV2 is a closed loop one based on CO_2 level. The HV1 strategy uses an open loop control based on presence detection. Fan control is stable in both cases (see Figure 7). This shows that the proposed hybrid ventilation strategies to switch between natural and mechanical mode are stable.

The strategy HV2 has a better indoor air quality performance than HV1 (see Figure 8 and Figure 9). In fact only the HV2 strategy includes a measurement of indoor air quality (CO_2 level) being a closed loop control.

HV1 uses lower fan speeds than HV1 and the fan is switched off for 50% of the simulation period (see Table 1). Hence the HV1 fan energy consumption has been reduced by 45% and the heating energy consumption is reduced by 4 % with respect to HV2 (see Table 2). In comparison, a typical mechanical ventilation system where the fan (with a fan power of about 40W) works continuously, the fan consumption is about 96 kWh for the same period of time.

For the thermal comfort, Table 3 shows that the operative temperatures in the habitable rooms are always in the acceptable range specified par ISO standard for occupant thermal comfort [1].

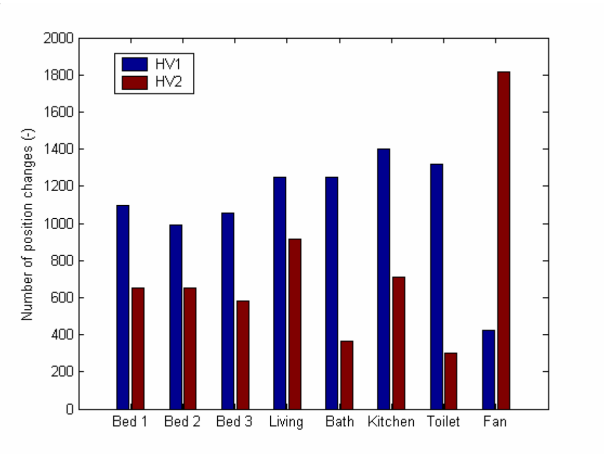


Figure 6. Number of Actuators Movements

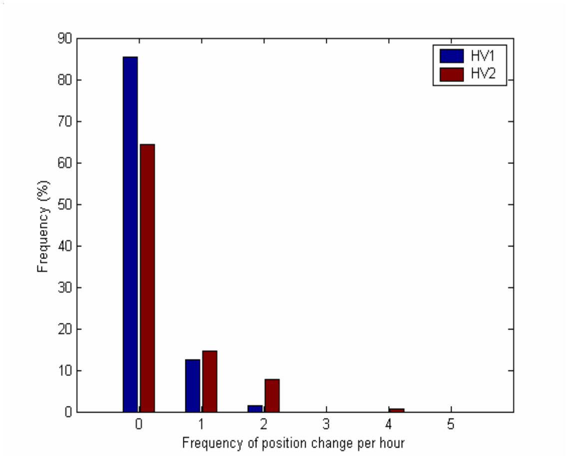


Figure 7. Frequency of Fan Position Change per Hour

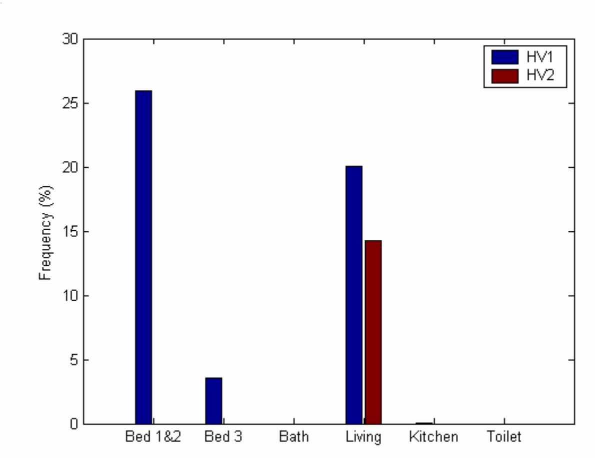


Figure 8. Frequency of Time when CO_2 Levels are Higher than 1050 ppm

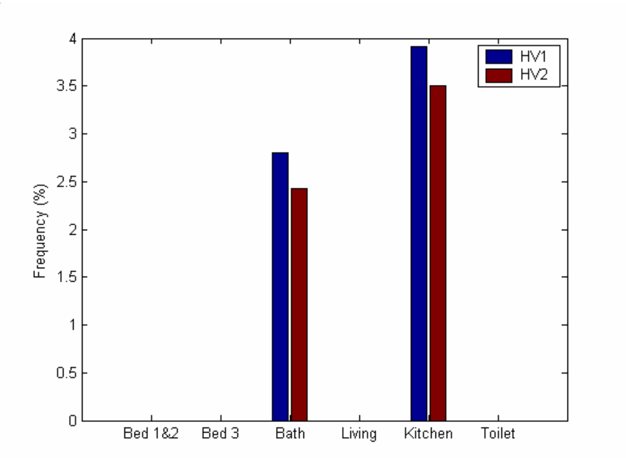


Figure 9. Frequency of Time when Relative Humidity Levels are Higher than 80%

Table 1. Fan Level Frequency

Control strategy	Number of level change	Fan level frequency			
		Fan off	level 1	level 2	level 3
HV1	420	50 %	48 %	2 %	0 %
HV2	1820	31 %	22 %	41 %	7 %

Table 2. Energy Consumption

	Heating energy Consumption	Fan Energy consumption
HV1	4500 kWh	3.5 kWh
HV2	4705 kWh	6 kWh

Table 3. Operative Temperature

		Operative Temperature			
		Bedroom 1	Bedroom 2	Bedroom 3	Living room
HV1	Min	19.8°C	19.8°C	19.8°C	19.7°C
	Max	21.1°C	21.1°C	20.9°C	22.4°C
HV2	Min	19.8°C	19.8°C	19.8°C	19.7°C
	Max	21.2°C	21.2°C	20.9°C	22.4°C

The simulation of these control strategies show that:

- Both strategies have good performance with respect to indoor air quality
- Both strategies optimize the use of the natural mode and are able to switch between the two modes with an acceptable magnitude of fan regime variation (on/off)
- The strategies show a very low energy consumption of fan with respect to traditional controlled mechanical ventilation.
- The fan is used for either 30 or 50% of the time (for the 3 winter months' period). In case of continuous functioning of the fan, there would have been over-ventilation particularly in the winter period and thus a higher heating demand.
- There is no major difference on the energy consumption over the heating period between the hybrid ventilation and a traditional controlled mechanical ventilation.
- It is important to take into account the control criteria in terms of movement in an overall ventilation control strategy assessment.

In order to promote such strategies, further work must be carried out on:

- The development of criteria to assess actuators life cycle
- The energy consumption of additional equipment required by the control systems (sensors, electronic devices energy consumptions). These seem to have a power of the about 1-2 W which might be running continuously for the whole year. If there are many sensors and actuators, this energy consumption is not neglible.

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APPENDIX A:

SENSORS DESCRIPTION CARDS

Temperature sensors

5 based on an electrical resistance measurement

Humidity sensors

5 based on an electrical capacitance measurement

1 based on length variation of a nylon strip

Infrared sensors

1 presence detector

1 agitation detector

CO2 sensor

Description card

author : Veldhuijzen	date : 07022003	Version : 1

Type : Sensor

Name : KTY 81-110

Principle : Resistance measurement proportional to temperature

Description :

Input(s) :		Action :		Parameter(s) :
temperature	⇒	Gives an analogical signal Proportional To temperature	⇐	Minimum value measured Maximum value measured

⇓

Output(s) :

490 to 2211 Ohm

Gives a linear signal between minimum value measured 490 Ohm (-55°C) to 2211 Ohm (150°C).

Description card

author : Veldhuijzen	date : 07022003	Version : 1

Algorithm :

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Temperature sensor

Name : Honeywell / INU Control GTR-01

Principle : Pt 100 Class B, DIN EN 60751

Description :

Input(s) :

Temperature

⇒

Action :

Gives an resistance proportional to temperature

⇐

Parameter(s) :

-50 - 150°C

⇓

Output(s) :

No information

Resistance: According to standard

Accuracy: According to standard

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Temperature sensor

Name : Regin TG-R530

Principle : Linear NTC sensor

Description :

Input(s) :		Action :		Parameter(s) :
Temperature	⇒	Gives an resistance proportional to temperature	⇐	0-30°C

⇓

Output(s) :

0°C - 12,5 kOhm
30°C - 10 kOhm

Linear output resistance between minimum value measured (12,5 kOhm) and maximum value measured (10 kOhm)

Accuracy: Better than ± 1°C

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Temperature sensor

Name : TAC EGRL

Principle : Thermistor

Description :

Input(s) :

Temperature

⇒

Action :

Gives an resistance proportional to temperature

⇐

Parameter(s) :

0-50°C

⇓

Output(s) :

1,8 kOhm
No detailed information

Resistance: 1,8 kOhm

Accuracy: Better than ± 0,6°C

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : sensor

Name : QAA24-27

Principle : Room temperature sensor
based on an electrical resistance measurement (LG-Ni1000)
Output signal proportional to temperature

Description :

Input(s) :		Action :		Parameter(s) :
Air temperature	⇒	Gives an analogous signal proportional to air temperature	⇐	Minimum value measured Maximum value measured

⇓

Output(s) :

0 - 10 VDC

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm : (equations, flow charts, functional scheme, …..)

If minimum value < temperature < maximum value then

$$\text{output} = \frac{10}{\text{maximum value} - \text{minimum value}} \times (\text{Temperature} - \text{minimum value})$$

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Humidity sensor

Name : TAC DIGHRL

Principle : Capacitive

Description :

Input(s) :

Humidity

⇒

Action :

Gives an analogical signal proportional to relative humidity

⇐

Parameter(s) :

0-100% RH

⇓

Output(s) :

4-20 mA

Linear output signal between minimum value measured (4 mA) and maximum value measured (20 mA)

Power supply: 10-28 VDC

Accuracy: >±3%, 10-90% RH

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

If minimum value < %RH < maximum value then

$$\text{output} = \frac{10}{\text{maximùum value} - \text{minimum value}} \times \%\text{RH} - \frac{10 \times \text{minimum value}}{\text{maximùum value} - \text{minimum value}}$$

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Humidity sensor

Name : Honeywell / INU Control

Principle : Capacitive

Description :

Input(s) :

Humidity

⇒

Action :

Gives an analogical signal proportional to relative humidity

⇐

Parameter(s) :

0-100% RH

⇓

Output(s) :

0-10V / 0-1V

Linear output signal between minimum value measured (4 mA) and maximum value measured (20 mA)

Power supply: 24VAC +20/-30%

Accuracy: ±5%, 10-90% RH

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

If minimum value < %RH < maximum value then

$$\text{output} = \frac{10}{\text{maximùum value} - \text{minimum value}} \times \%\text{RH} - \frac{10 \times \text{minimum value}}{\text{maximùum value} - \text{minimum value}}$$

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : Humidity sensor

Name : Calectro EHF-32/50A

Principle : Capacitive

Description :

Input(s) :

Humidity

⇒

Action :

Gives an analogical signal proportional to relative humidity

⇐

Parameter(s) :

0-100% RH

⇓

Output(s) :

4-20 mA

Linear output signal between minimum value measured (4 mA) and maximum value measured (20 mA)

Power supply: 10-30 VDC

Accuracy: ±2%, 10-90% RH

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

If minimum value < %RH < maximum value then

$$\text{output} = \frac{10}{\text{maximùum value} - \text{minimum value}} \times \%\text{RH} - \frac{10 \times \text{minimum value}}{\text{maximùum value} - \text{minimum value}}$$

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : sensor

Name : QFA65

Principle : Relative humidity sensor
based on an electrical capacity measurement
Output signal proportional to relative humidity

Description :

Input(s) :

Relative humidity

⇒

Action :

Gives an analogical signal proportional to relative humidity

⇐

Parameter(s) :

Minimum value measured

Maximum value measured

⇓

Output(s) :

0 - 10 VDC

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

If minimum value < relative humidity < maximum value then

$$\text{output} = \frac{10}{\text{maximum value} - \text{minimum value}} \times (\text{Relative humidity} - \text{minimum value})$$

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : sensor

Name : NOS-RF

Principle : Relative humidity sensor
based on an electrical resistance measurement
Output signal proportional to relative humidity

Description :

Input(s) :		Action :		Parameter(s) :
Relative humidity	⇒	Gives an analogous signal proportional to relative humidity	⇐	Minimum value measured Maximum value measured

⇓

Output(s) :
0 - 10 VDC

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

If minimum value < relative humidity < maximum value then

$$\text{output} = \frac{10}{\text{maximum value} - \text{minimum value}} \times (\text{Relative humidity} - \text{minimum value})$$

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : (Mechanical) Relative humidity detector

Name : (Mechanical) Relative humidity detector

Principle : Lengthening of nylon strips according to relative humidity around, that drive a mechanical system whose displacement can also be converted in an electric signal.

Description :

Input(s) :

Relative humidity (RH%) of the room in which the inlet is installed.

⇒

Action :

Providing increasing signal according to relative humidity inside the room.

⇐

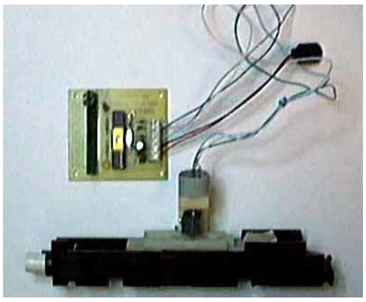
Parameter(s) :

Minimum and maximum signal level.
Expected relation between output signal and RH%.

⇓

Output(s) :

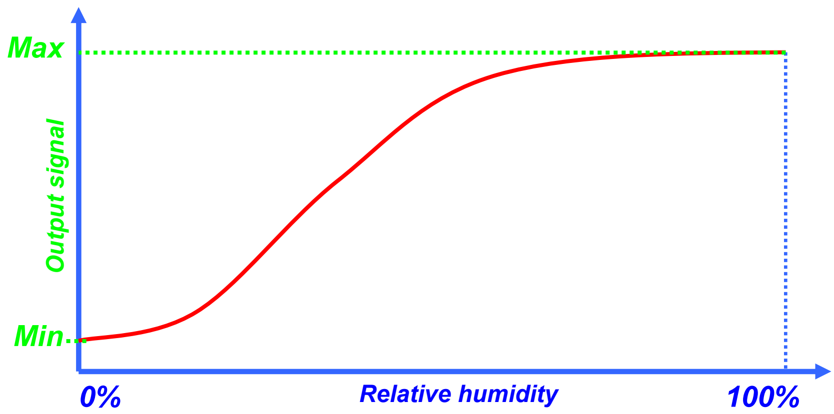
"Analogical" or numerical signal from minimum to maximum signal level.



Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :



Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Presence detector

Name : Presence detector

Principle : Infra-red sensor detecting presence of people in a room or not.

Description :

Input(s) :

Presence or not of people inside the room where installed.

⇒

Action :

Provide 0/1 signal according the presence or not of people in the room.

⇐

Parameter(s) :

Minimum and maximum distance from the sensor.

⇓

Output(s) :

ON/OFF signal

Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

- Motion (human type speed) detected => send “1” signal
- No notion (human type speed) detected => send “0” signal

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Agitation detector

Name : Agitation detector

Principle : Infra-red sensor evaluating agitation of people in a room.

Description :

Input(s) :

Global motions of people inside the room where installed.

⇒

Action :

Provide increasing signal according to the agitation of people in the room.

⇐

Parameter(s) :
Minimum and maximum signal level “l”.
Number “n” of detection levels.
Minimum and maximum distance from the sensor.

⇓

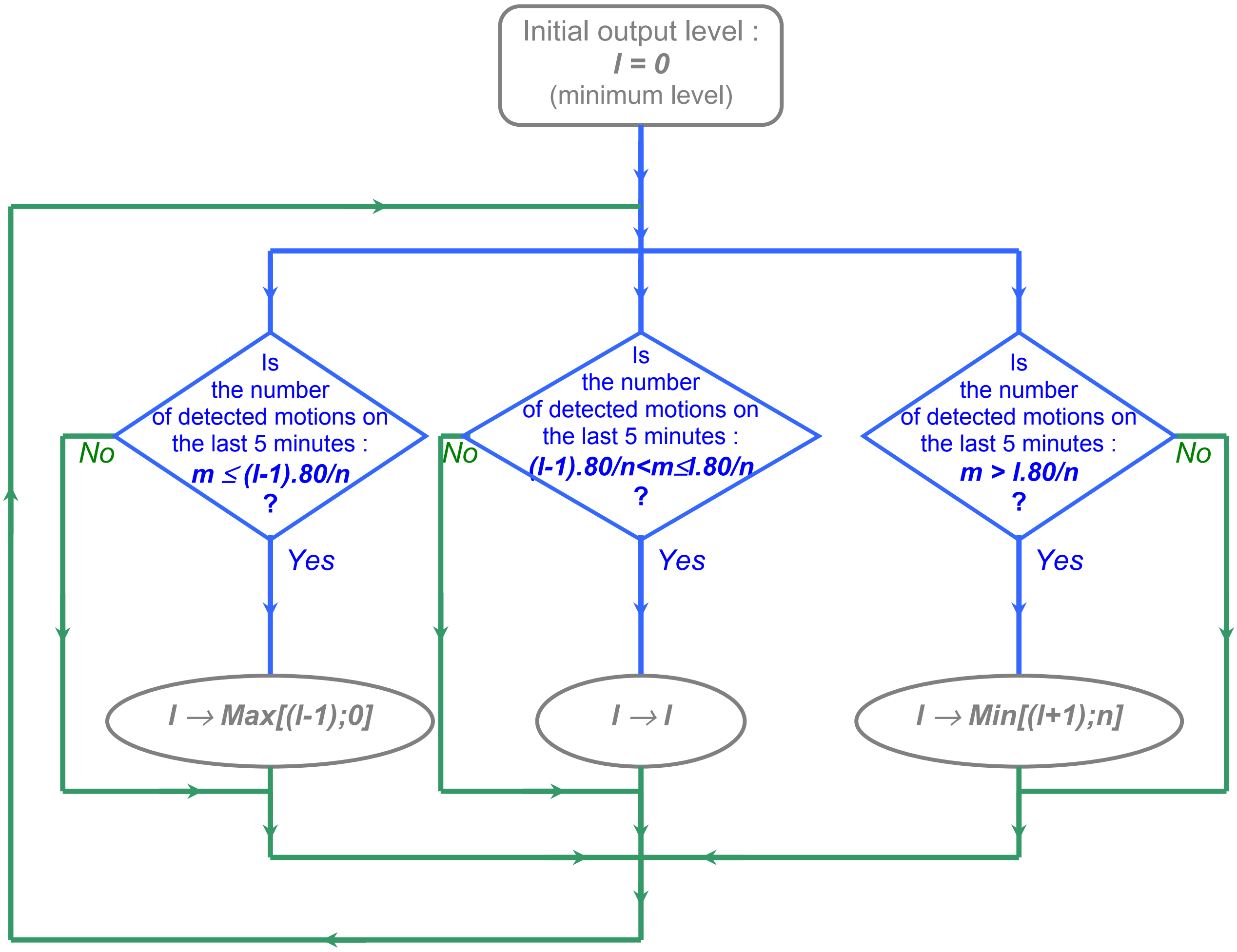
Output(s) :

“Analogical” or numerical signal from minimum to maximum signal level.

Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :



Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Sensor

Name : AQS

Principle : Infrared measurement of CO_2 concentration ;
Output signal proportional to CO_2 concentration

Description :

Input(s) :		Action :		Parameter(s) :
CO_2 (ppm)	⇒	Gives an analogous signal proportional to CO_2 concentration	⇐	Minimum value measured Maximum value measured

⇓

Output(s) :

0 – 10 VDC

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

If minimum value < CO2 concentration < maximum value then

$$\text{output} = \frac{10}{\text{maximum value} - \text{minimum value}} \times (\text{CO2 - concentration} - \text{minimum value})$$

APPENDIX B:

ACTUATORS DESCRIPTION CARDS

Electric motors

1 stepper motor (rotation depending on number of pulses)

1 DC motor

Damper

Electric window

3 in 24 V DC

1 in 230 V AC

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Actuator

Name : Z26000

Principle : Stepper motor
which converts electrical pulses into specific rotational movements

Description :

Input(s) :

Electrical pulse(s) VDC

⇒

Action :

Rotation depending on number of electrical pulses

⇐

Parameter(s) :

Step angle

⇓

Output(s) :

Rotation angle

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

Rotation (°) = number of pulses applied x step angle (°/pulse)

Depending on full/half stepping and unipolar/bipolar type of motor

Description card

author : Veldhuijzen	date : 07022003	Version : 1

Type : Register

Name : confirm.

Principle : Register is positioned in combination with an air heat exchanger. If heat recovery function is not wished, the register opens, cool outside air can stream into the dwelling

Description :

Input(s) :		Action :		Parameter(s) :
Temperature outside air Temperature inside air	⇒	Open or close the register Depending on algorithm.	⇐	Set point dwelling temp. TC Outside air temp. T1 Measured dwell. Temp. T3

⇓

Output(s) :

490 to 2211 Ohm

Gives a linear signal between minimum value measured 490 Ohm (-55°C) to 2211 Ohm (150°C).

Description card

author : Veldhuijzen	date : 07022003	Version : 1

Algorithm :

Bypass register open if TC < T3 AND T1 < T3

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Type : actuator

Name : Belimo LM24-SR

Principle : electric actuator
which can rotate from 0 to "maximum rotation" degrees

Description :

Input(s) :

Direct current 0-10 V
Operating range 2-10 V

⇒

Action :

Rotation depending on direct current and maximum rotation

⇐

Parameter(s) :

Maximum rotation 95º

⇓

Output(s) :

Angle : 0 to "maximum rotation"
Signal: 2-10 VDC

Description card

author : J Brock	date : 2003-03-19	Version : 1a

Algorithm :

$$\text{angle} = \text{direct current} \times \frac{\text{maximum rotation}}{10}$$

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Actuator

Name : Twinmaster

Principle : 24 VDC electric window operator with electronic end-stop for building upon window profiles, which can open a window between 0 to maximum 380 mm.

Description :

Input(s) :

Power: 24 VDC

⇒

Action :

Linear stroke of chain depending on supply voltage and chain speed

⇐

Parameter(s) :

Chain speed

⇓

Output(s) :

Chain position (mm): 0 to maximum

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

Chain stroke (mm) = time period of power applied (s) x chain speed (mm/s)

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Actuator

Name : WMX 820 01 standard

Principle : 24 VDC electric window operator with electronic end-stop for concealed installation in window profiles, which can open a window between 0 to maximum 500 mm.

Description :

Input(s) :

Power: 24 VDC

⇒

Action :

Linear stroke of chain depending on supply voltage and chain speed

⇐

Parameter(s) :

Chain speed

⇓

Output(s) :

Chain position (mm): 0 to maximum

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

Chain stroke (mm) = time period of power applied (s) x chain speed (mm/s)

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Actuator

Name : WMX 802 01 standard

Principle : 24 VDC electric window operator with electronic end-stop for concealed installation in window profiles, which can open a window between 0 to maximum 265 mm.

Description :

Input(s) :

Power: 24 VDC

⇒

Action :

Linear stroke of chain depending on supply voltage and chain speed

⇐

Parameter(s) :

Chain speed

⇓

Output(s) :

Chain position (mm): 0 to maximum

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

Chain stroke (mm) = time period of power applied (s) x chain speed (mm/s)

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Type : Actuator

Name : Supermaster

Principle : 230 VAC electric window operator with electronic end-stop for building upon window profiles, which can open a window between 0 to maximum 600 mm.

Description :

Input(s) :

Power: 230 VAC

⇒

Action :

Linear stroke of chain depending on supply voltage and chain speed

⇐

Parameter(s) :

Chain speed

⇓

Output(s) :

Chain position (mm): 0 to maximum

Description card

author : Ivan Pollet (Renson)	date : 20-02-2003	Version : 1

Algorithm :

Chain stroke (mm) = time period of power applied (s) x chain speed (mm/s)

APPENDIX C:

SENSOR AND ACTUATOR IN A SINGLE COMPONENT

Humidity controlled components

4 inlets (1 with good acoustic properties)

1 outlet

Humidity and presence controlled outlet

Presence controlled outlet

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Adjustable Air Inlet

Name : EMM

Principle : Air inlet for natural (or mechanical) ventilation which opens according to indoor relative humidity

Description :

Input(s) :

Relative humidity of the room in which the inlet is installed.

Difference of pressure between downstream and upstream the grille.

⇒

Action :

Adjusting entering airflow in the room according to its relative humidity : increasing proportionally airflow when relative humidity increases and conversely.

⇐

Parameter(s) :

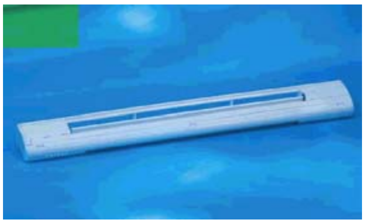
Minimum airflow for a 10 Pa pressure difference.
Maximum airflow for a 10 Pa pressure difference.

Minimum relative humidity.
Maximum relative humidity.

⇓

Output(s) :

Airflow from minimum airflow to maximum airflow.

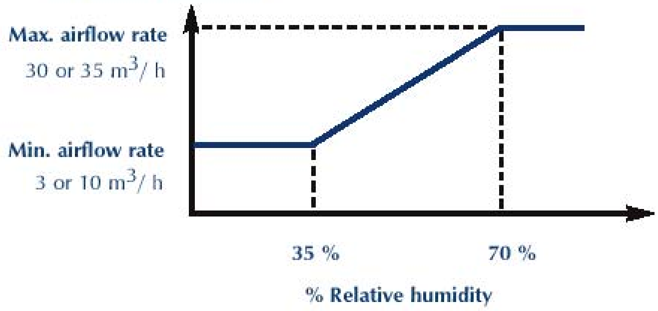


Description card

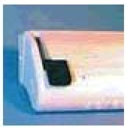
author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS



Observation : There is an optional blanking cover allowing the air inlet to be returned manually to its «min. flow rate» setting.



Characteristics of EMM air inlets

TECHNICAL	min.	max. (vertical flow)	max. (oblique flow)	Type
Flow rates in m^3/h at 10 Pa	3 10	30 30	35 35	EMM 3-30 EMM 10-30
% Relative internal humidity	35 %	70 %		
Fixed flow rate in m^3/h at 10 Pa	22 30			EMF 22 EMF 30
ACOUSTICS	Dne route	Dne rose		Combination
Attenuation EMM open	33 dB(A) 37 dB(A)	33 dB(A) 36 dB(A)		EMM on its own EMM + acoust Canopy

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Air Inlet

Name : EAH

Principle : Air inlet for natural (or mechanical) ventilation which opens according to indoor relative humidity

Description :

Input(s) :
Relative humidity of the room in which the inlet is installed.
Difference of pressure between downstream and upstream the grille.

⇒

Action :

Adjusting entering airflow in the room according to its relative humidity : increasing proportionally airflow when relative humidity increases and conversely.

⇐

Parameter(s) :
Minimum airflow for a 10 Pa pressure difference.
Maximum airflow for a 10 Pa pressure difference.
Minimum relative humidity.
Maximum relative humidity.

⇓

Output(s) :

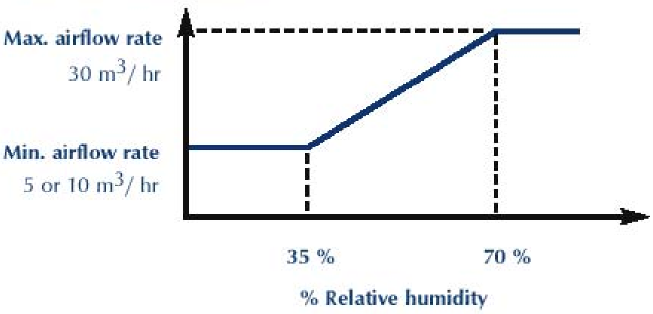
Airflow from minimum airflow to maximum airflow.

Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS



Observation : There is an optional blanking cover allowing the air inlet to be returned manually to its « min. flow rate » setting.

Characteristics of EAH air inlets

TECHNICAL	min.	max.	Type
Flow rates in m3/hr at 10 Pa	5 10	30 30	EAH 5-30 EAH 10-30
% Relative internal humidity	35 %	70 %	
ACOUSTICS			
Attenuation, EAH open	up to 42 dB(A) with the acoustic sleeve		

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Air Inlet

Name : EHT

Principle : Wall air inlet for natural (or mechanical) ventilation which opens according to indoor relative humidity

Description :

Input(s) :
Relative humidity of the room in which the inlet is installed.

Difference of pressure between downstream and upstream the grille.

⇒

Action :

Adjusting entering airflow in the room according to its relative humidity : increasing proportionally airflow when relative humidity increases and conversely.

⇐

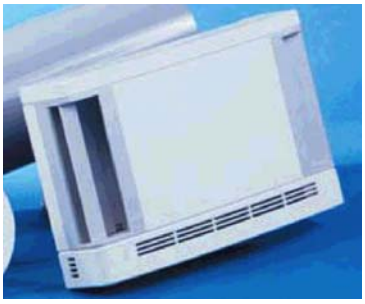
Parameter(s) :
Minimum airflow for a 10 Pa pressure difference.
Maximum airflow for a 10 Pa pressure difference.

Minimum relative humidity.
Maximum relative humidity.

⇓

Output(s) :

Airflow from minimum airflow to maximum airflow.

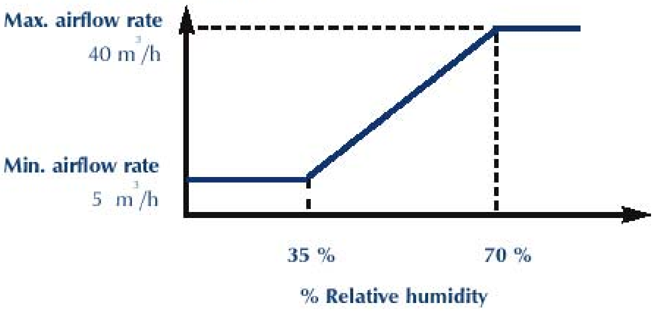


Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS



Observation : There is an optional closing device allowing the air inlet to be manually closed to minimum.

Characteristics of EHT air inlets

TECHNICAL	min.	max.	Type
Flow rates in m^3/h at 10 Pa	5	40	EHT 5-40
% Relative internal humidity	35 %	70 %	
ACOUSTICS			
Proper noise	from 20 to 21 dB(A) under 10 Pa		

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Acoustic Air Inlet

Name : EHA

Principle : Air inlet with acoustic performance
for natural (or mechanical) ventilation
which opens according to indoor relative humidity

Description :

Input(s) :

Relative humidity of the room in which the inlet is installed.
Difference of pressure between downstream and upstream the grille.
External noise.

⇒

Action :

Adjusting entering airflow in the room according to its relative humidity : increasing proportionally airflow when relative humidity increases and conversely.
Attenuating external noise

⇐

Parameter(s) :
Minimum airflow for a 10 Pa pressure difference.
Maximum airflow for a 10 Pa pressure difference.

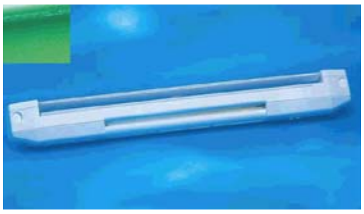
Minimum relative humidity.
Maximum relative humidity.

⇓

Output(s) :

Airflow from minimum airflow to maximum airflow.

Low noise from outside.

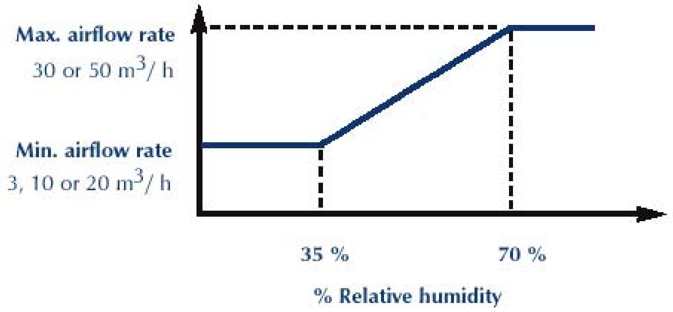


Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS



Observation : There is an optional blanking cover (for the EHA 3-35 only) allowing the air inlet to be returned manually to its «min. flow rate» setting.

Characteristics of EHA / EFA air inlets

TECHNICAL	min.	max.	Type
Flow rates in m^3/h at 10 Pa	3 10 20	35 35 50	EHA 3-35 EHA 10-35 EHA 20-50
% Relative internal humidity	35 %	70 %	
Fixed flow rate in m^3/h at 10 Pa	22 30		EFA 22 EFA 30
ACOUSTICS			
Attenuation EHA open	According to combinations, from 36 dB(A) to 42 dB(A) for types EHA 3-35 and EHA 10-35 Attenuation of 35 dB(A) for the EHA 20-50		

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Extract Unit

Name : GHN

Principle : Extract grille for natural ventilation
which opens according to indoor relative humidity

Description :

Input(s) :
Relative humidity of the room in which the grille is installed.

Difference of pressure between downstream and upstream the grille.

⇒

Action :

Adjusting entering airflow in the room according to its relative humidity : increasing proportionally airflow when relative humidity increases and conversely.

⇐

Parameter(s) :
Minimum airflow for a 10 Pa pressure difference.
Maximum airflow for a 10 Pa pressure difference.

Minimum relative humidity.
Maximum relative humidity.

⇓

Output(s) :

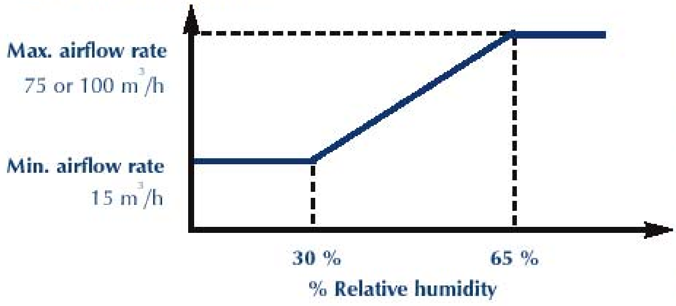
Airflow from minimum airflow to maximum airflow.

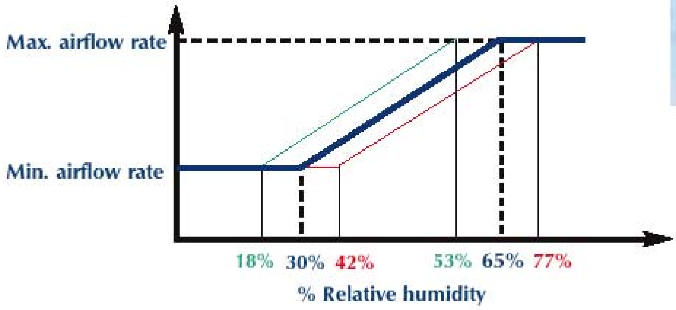
Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS





Characteristics of GHN extract units

TECHNICAL	min.	max.	Number of plates remaining*
Flow rates in m^3/h at 10 Pa	15	75	4
	15	100	0
% Relative internal humidity	30 %	65 %	

* 4 removable plates allow the opening surface to be increased on the bracket version.

Observation

it is possible to adjust the range of humidity of the GHN by moving the Relative Humidity curve by +/-12 % by an index.

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Humidity Sensitive Extract Unit with Motion Sensor

Name : BXS

Principle : Extract grille for mechanical ventilation which opens according to indoor relative humidity and indoor occupancy

Description :

Input(s) :
Relative humidity of the room in which the grille is installed.

Presence or not of people inside the room where installed.

Difference of pressure between downstream and upstream the grille.

⇒

Action :
Ensuring at least :

- Adjusting extracted airflow in the room according to its relative humidity : increasing airflow when relative humidity increases and conversely.
- Reaching minimum air flow if nobody detected in the room. Reaching maximum air flow if somebody detected in the room.

⇐

Parameter(s) :

Minimum airflow for a 100 Pa pressure difference. Maximum airflow for a 100 Pa pressure difference.

Minimum and maximum distance from the sensor.

⇓

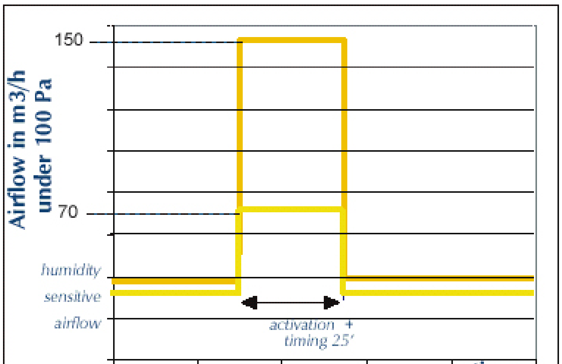
Output(s) :

Airflow from minimum airflow to maximum airflow.

Description card

author : AERECO	date : 04/02/2003	Version : 1

Airflow characteristics



The timing is activated through :
- action of the peak airflow when the switch/pull cord has been activated
- maintain the peak airflow when the occupants have left the room (version with motion sensor)

	Reference	Airflow in m3/h under 100 Pa		Peak airflow in m3/h under 100 Pa	Timing version (During of timing 25')
		mini*	maxi**		
BXS	BXS883EX / BXS876EX	12	70	70	on/off switch / motion sensor
	BXS884EX / BXS880EX	12		70	on/off switch / motion sensor
	BXS860EX	12	70	-	-

Description card

author : AERECO	date : 04/02/2003	Version : 1

Type : Extract Unit with Motion Sensor

Name : TDA

Principle : Extract grille for mechanical ventilation which opens according to indoor occupancy

Description :

Input(s) :

Presence or not of people inside the room where installed.

Difference of pressure between downstream and upstream the grille.

⇒

Action :

Reaching minimum air flow if nobody detected in the room.

Reaching maximum air flow if somebody detected in the room.

⇐

Parameter(s) :

Minimum airflow for a 100 Pa pressure difference.

Maximum airflow for a 100 Pa pressure difference (4 possible tunings).

Minimum and maximum distance from the sensor.

⇓

Output(s) :

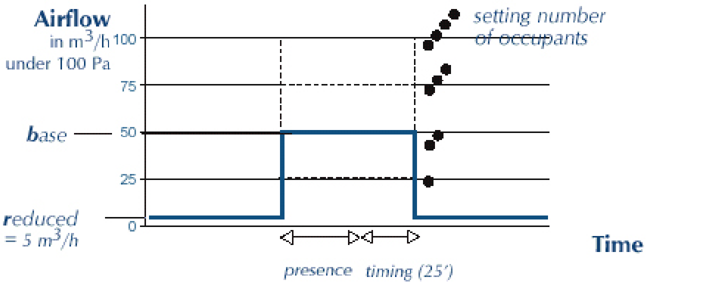
Either minimum airflow or maximum airflow.

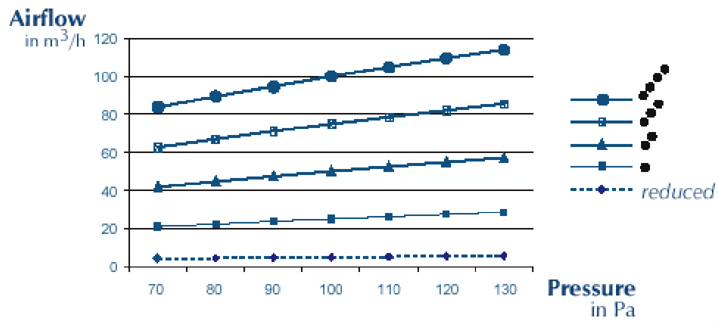
Description card

author : AERECO	date : 04/02/2003	Version : 1

Algorithm :

CHARACTERISTICS





Characteristics of TDA

Typical occupation *	Setting	Base airflow in m^3/h**	Reduced airflow in m^3/h**	Proper noise Lw in dB(A) at 100Pa (Lw at 4 m)
4 persons		100	5	33,3 (12,8)
3 persons		75	5	32,2 (11,4)
2 persons		50	5	30,3 (10)
1 person		25	5	30 (11,1)

*Indicative average number. Depends on requirement for air quality. See the valid regulation in the country.
** under 100Pa.

References :
with 9V battery :................................ TDA874EX
for 12V AC electrical network: TDA873EX

APPENDIX D:

COMMUNICATION TECHNOLOGIES

(Input for State of the Art document of work package 1)

The evolution of building automation and direct digital control in the 1980's has favoured the developement of communication technologies in buildings. Today building automation system offer two main possibilities to integrate the control of different equipment/applications in a building:

- Proprietary systems,
- Open systems.

A proprietary system is a closed system that is developed by a single manufacturer/contrator. The latter holds the knowledge underlying the developement of the system. In such systems, the initial costs might be relativeley low and easy to set up, but the building owner is locked into products of a single manufacturer and can hardly take advantage of innovative technologies. Any new technology that uses another protocol require intergation by the manufacturer.

An open system is one where in standards are developed, published and maintained by an independant recognised organisation (CEN, ASHRAE/ANSI…). Any change to the system requires the comments of users, industry, professionals before being approved by the standards / organisation. Open communication protocols are now becoming used for the integration of equipment from different manufacturers. This offers the following benefits:

- Media sharing: different products from different manufacturers run on the same communications cables,
- Vendor independance: it applies for initial purchase of different equipment and / or system extension.

Both sytem architecture have the following capabilities:

- Connection of different building applications: HVAC, lighting, solar protections, fire, access/security…
- Single supervision: all services can be viewed from one user interface.

Standardisation of protocols

The Cen 247 WG4 has been working on standardisation of data transmission methods between products and systems for HVAC applications. This working group has divided the communication within a building automation system into 3 types of communication requirements:

- The Management net: workstation to workstation communication,
- The automation or control net: plant controllers and workstations,
- The field net: terminal unit controllers, sensor devices, drives…

The work of CEN TC247 is to enhance the implementation of BAS (Building Automation System) by supporting a number of standards. To bring down cost, the standardisation work promotes open systems architecture.

The table below gives a list of communication protocols and the media that are required:

Level	Protocol	Transmission Media
Management	BACnet	Ethernet, PSTN / dial up modem
	WorldFIP	Twisted pair
Automation	BACnet	Ethernet, LONtalk, PSTN / dial up modem
	EIB	Ethernet
	PROFIBUS	PROFIBUS FMS - twisted pai
Field	EIB	Twisted pair, Mains signalling
	BATIBUS	Twisted pair
	LONtalk	Twisted pair, Mains signalling, radio…

Adapted from: BCG group - UK

Some commonly used open standards have not been recognised by TC 247. But will remains in use:

- MODBUS which is often used to attach HVAC plant modules such as a chiller to a BAS.
- IT standards such as Microsoft COM, DCOM or internet standards (TCP/Ip, HTTP…) which is used at management level.

Some open communication systems are listed below:

1. BACnet (http://www.bacnet.org/) – The Building Automation and Control network was developed by ASHRAE nad is now publihed as an ASHRAE/ANSI standard and a CEN standard.
2. LonWorks (http://www.echelon.com/) developed by Echelon in the USA. It is a general purpose network using the LonWorks protocol and the « Neuron » chip. It is most suitable for device-level integration and widely used in buildings on twisted pair using a transceiver known as FTT-10.
3. MODBUS (Jbus) designed by Gould Modicon Company is not an officiel standard and is supported by most Programmable Logic Controllers (PLC). It relies on a Master/Slave serial protocol.
4. Konnex (http://www.konnex.org) is the result of the merging of 3 communication systems namely BATIBUS, EIB and EHS.
5. PROFIBUS (http://www.profibus.com/) developed by The German Federal Government for Research and Technology together with Siemens. It is mainly used on industrial sites.
6. WorldFIP (Http://www.worldfip.org) developed in France and has achieved the status of a European Standard.

The main issue for the success of integrated solutions in residential buildings is to define the appropriate communication protocol and the media for information transfer. It is most likeley that BACnet, Konnex and LonWork will be the major actors in this field.

Communication media in residential buildings

3 main communication medias are used in residential buildings:

- specific wires,
- radio,
- PLC using existing main network.

Radio and PLC are very attractive for use in retrofit of buildings since they avoid the need for new wiring which is otherwise very expensive.

Extending building automation systems to ventilation

Building automation has been extensively used for heating and air conditioning systems. There is currently a trend to increase automation of ventilation systems. The automation process is enhanced by merging technologies of temperature and ventilation controls in the BAS. In fact current BAS offer on-line information of different caracteristics of the building that is required by the heating and /or airconditioning system. Such information include temperature in different zones, humidity level in ducts, pressure sensors, presence sensors…

Intergation of control of ventilation system in the BAS will promote sharing of equipment such as sensors (pressure sensor, presence/motion sensor…) or in some cases sharing of drives. Besides some sensors that are typically required by ventilation control systems (CO_2 sensors, humidity sensor…) might be useful for the air conditioning system to ensure better indoor air quality and comfort of the occupants. In general, communication between ventilation system and other technical systems will increase the possibility for optimum use of the different systems to improve 1) people's comfort 2) reduce energy consumption. Furthermore the fact that there is sharing of equipment (sensors, drives, communication cables…), and the possibilities to supervise the whole systems simultaneaously, will lead to reduce maintenance cost by careful monitoring of all equipment.

The effort of bringing more communication between equipment or systems has also promoted decentralisation of intelligence to the field level. Terminal control units or sensor are now smart and are quite autonomous. This reduces the amount of information to be transmitted on the network and makes the overall system more robust. In ventilation systems, this type of decentralised intelligences has been used for a very long time for example in humidity-controlled systems where the extraction grilles had modulated flow rates with respect to humidity concentration in kitchen or toilets. These systems were stand alone and could not provide any information to other equipment such as the heating systems. Nowadays products are available with increased intelligence thanks to the development and reduced cost of micro-chips.Electronic air inlets (for example from Alusta) or intelligent sensors (for exapmle from SenseAir) allow for a certain aount of decison-taking capabilities locally and reduce the number of communication data with higher control levels.

It is expected that the development of BAS in residential building will necessarily include such intelligent field level devices.