Controlled mechanical ventilation (CMV) in residential buildings

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GENERAL ISSUES: WHY VENTILATION?

Yesterday:

- numerous leaks, infiltration through windows and doors
- high consumption for heating

Today:

- Airtight Buildings
- Low permeability to outside air

Natural air change is impossible.

GENERAL ISSUES: WHY VENTILATION?

Main indoor pollutants:

1. VOCs (volatile organic compounds): benzene, toluene, formaldehyde, oxygenated compounds
2. Gases produced by combustion
3. Airborne particulate matter
4. Bacteria, molds and other organisms
5. Organic by-products of animals and humans
6. Asbestos and mineral fibers
7. Radon
8. Cigarette smoke

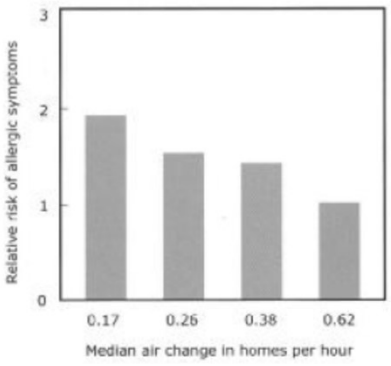
MOISTURE IN BUILDINGS

BUILDING: Unavoidable presence of moisture:

- normal air composition;
- consequence of vapor production for activities performed by users.

physiologic

pathologic



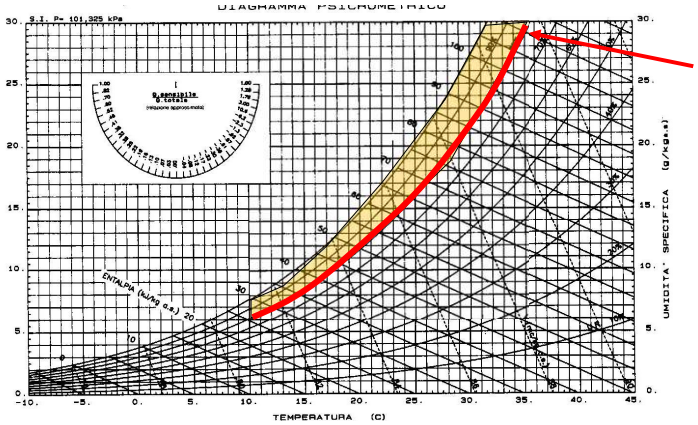
Bornehag et al. 2005

THE CONSEQUENCES OF INADEQUATE ACR

A) SURFACE CONDENSATION (possible appearance of mold)

B) INTERSTITITIAL CONDENSATION (possible deterioration of building materials and decrease in the thermal insulation)

C) LOW INTERNAL AIR QUALITY (onset of pathologies).



Local relative humidity range causing mold growth

THE IMPORTANCE OF VENTILATION

VENTILATION OF INDOOR ENVIRONMENTS:

It is a fundamental human need;

It is indispensable for the preservation of the building structure;

It must not be considered a "burden";

It involves an energy requirement that varies depending on the technology adopted;

THE IMPORTANCE OF VENTILATION

- Dilution and removal of indoor pollutants
- Dilution of specific pollutants (odors from toilets - cooking vapors)
- Ensure air for metabolic activity of occupants
- Ensure control of indoor humidity and avoid the formation of condensation and subsequently mold
- Providing the right amount of combustion air in the presence of gas appliances for domestic use

POSSIBILITIES FOR AIR CHANGE

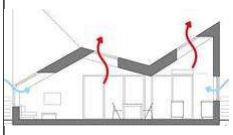
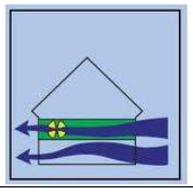
⇨ **1: Opening of window frames (AERATION) and infiltration**

2: Natural ventilation

3. Mechanical ventilation

4. Hybrid ventilation

} **System design**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AERATION AND VENTILATION

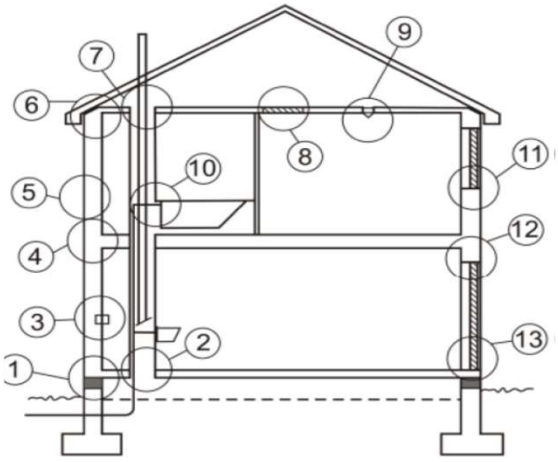
There is a frequent misunderstanding about the concept of ventilation in residential construction.

The UNI EN 12792:2005 Standard highlights the difference between "ventilation" and "aeration":

The term ventilation indicates a method of air exchange by opening windows. Ventilation, on the other hand, means the intake and corresponding extraction of air, both calculated, into and from a given space.

The Standard UNI EN 16798:2019, also clearly specifies that ventilation must be continuous in buildings when occupied, and can be decreased, but not canceled, when they are not. The same Standard indicates ventilation rates, at times of occupancy of housing, significantly higher than those tended to be suggested by energy assessment procedures and the same UNI TS 11300-1.

INFILTRATION



NATURAL VENTILATION

When openings are placed in the building envelope, the pressure differential between the various facades (or between different areas of the same facade) generated by the wind and/or the difference in temperature (and therefore density between the exterior and interior) gives rise to an internal airflow, which can be used for ventilation.

NATURAL VENTILATION

Pressure uses the principle of the chimney effect: warm air, which is lighter than cold air, tends to rise, drawing in more cold air. The temperature differences in the various rooms of the house determine a ventilation that allows the air to be exchanged.

The depression exploits the effect of the wind: when a building is hit by the wind, the wall directly exposed is subject to a strong pressure, while the wall located on the opposite side (downwind) is affected by a depression. The difference in pressure between the two facades is sufficient to create a natural ventilation of the rooms.

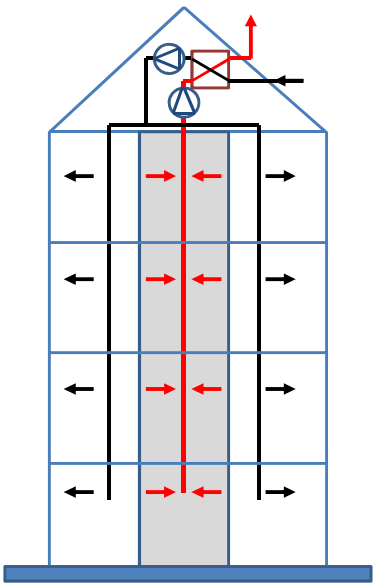
Ventilation according to EN 12792

Balanced ventilation (dual flow):

Air is supplied and taken back into the rooms.
There is a supply fan with fresh air
There is an expulsion fan with exhausted air

Pro:
- **Possibility of thermal recovery**
- **Possibility of air treatment with cooling and dehumidification coils**
- **Possible integration with GAHE (air-ground exchangers)**
- **Good air flow control**
- **Centralized maintenance**

Cons:
- **High costs;**
- **In case of more users, impossibility of autonomous management of the plant**



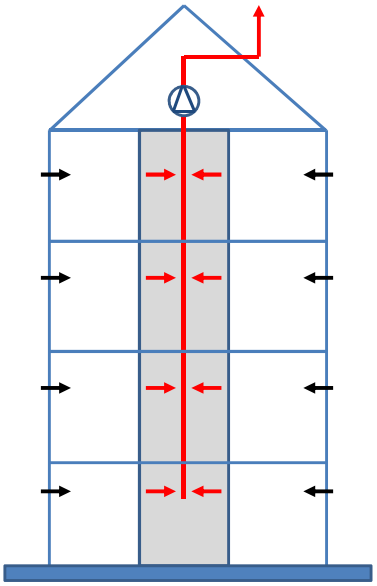
Ventilation according to EN 12792

Exhaust ventilation (single flow):

The air is returned to the rooms.
There is an exhaust fan for the exhausted air
The air enters through openings in the casing or in the window frames

Pro:
- **Inexpensive;**
- **Adjusts the opening of the vents according to the relative humidity (and therefore the actual presence of people)**

Cons:
- **Maintenance delegated to the user**
- **In case of more users, impossibility of autonomous management of the plant**
- **It does not allow heat recovery (unless you put a Heat Pump on the expulsion)**
- **There is no control on the flow rate actually entering the single environment**
- **Inlet air cannot be pre-handled**



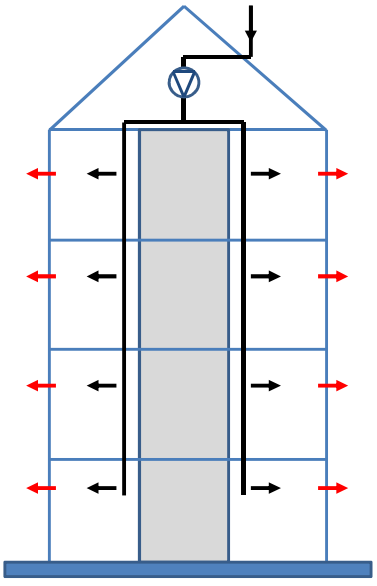
Ventilation according to EN 12792

Supply ventilation (single flow):

Air is returned to the rooms.
There is a supply fan with fresh air
The air exits through openings in the casing or in the window frames

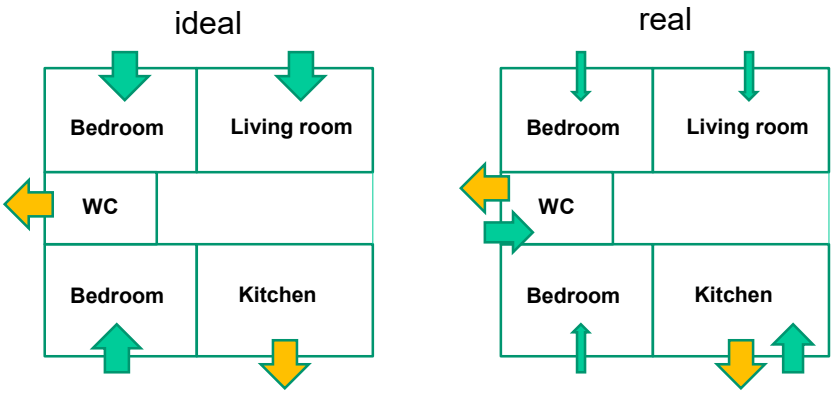
Pro:
- **Possibility of air handling with cooling and dehumidification coils**
- **Possible integration with GAHE (air-ground exchangers)**
- **Good control of air flows**

Cons:
- **Maintenance delegated to the user**
- **In case of more users, impossibility of autonomous management of the plant**
- **Does not allow heat recovery**
- **Difficulty in balancing flows in operating conditions**

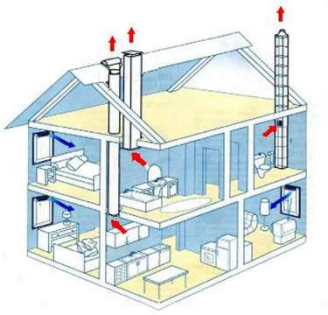
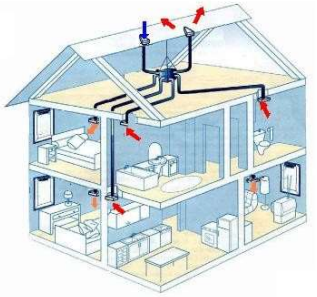


Criticality of single-flow (exhaust) vs. dual-flow ventilation

- Enclosure losses are greater than air flowing from vents
- Air enters predominantly negative pressure environments
- Result: lower effective air flow rate into the room

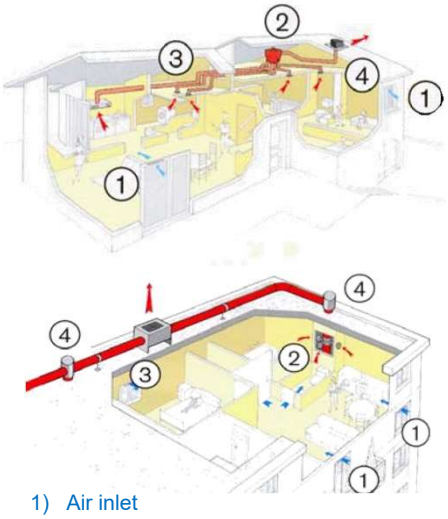


Mechanical ventilation

Single flow	The system provides the mechanical extraction of the stale air while the inflow of external air takes place through outlets equipped with devices for the flow rate self-regulation.	
Dual-flow	The system provides the mechanical extraction of the stale air and the contemporary introduction of fresh air which can be previously filtered and/or pre-heated before being introduced into the system.	

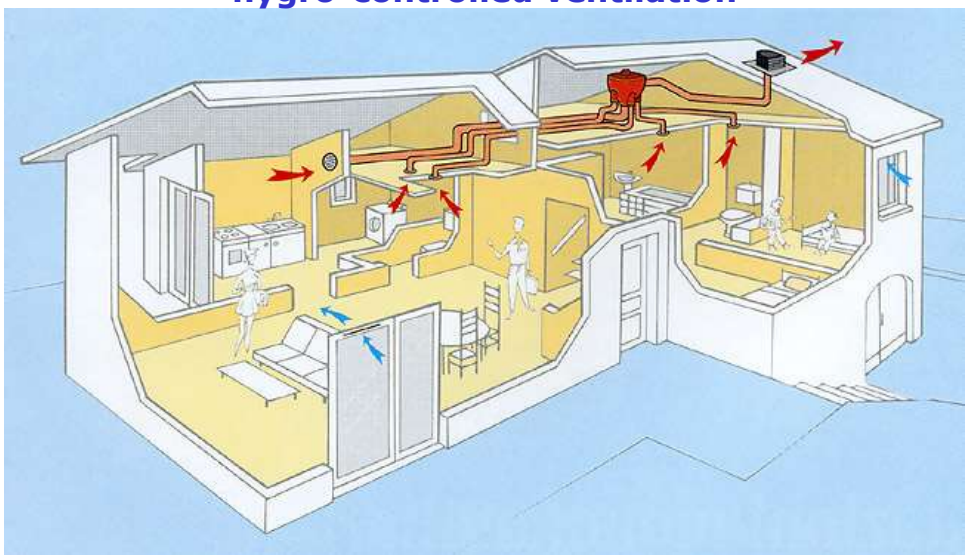
Mechanical ventilation – Single flow

- The system consists of a small electric fan for air extraction connected by rigid and/or flexible ducts to extraction grilles located in the service rooms (kitchen and bathrooms).
- The inflow of external air takes place by means of vents, placed on the external walls or on the window frames of the "main" rooms (living room and bedrooms), equipped with self-regulating flow rate devices or devices sensitive to the relative humidity of the environment.
- For centralized condominium installation, a single fan is installed (in the attic or outdoors) from which a series of ducts branch out connecting the risers.



1) Air inlet
2) Extraction
3) Ducts
4) Exit on the roof

Single-family flow (self-regulating or) hygro-controlled ventilation



Mechanical ventilation – Single flow

Pro:

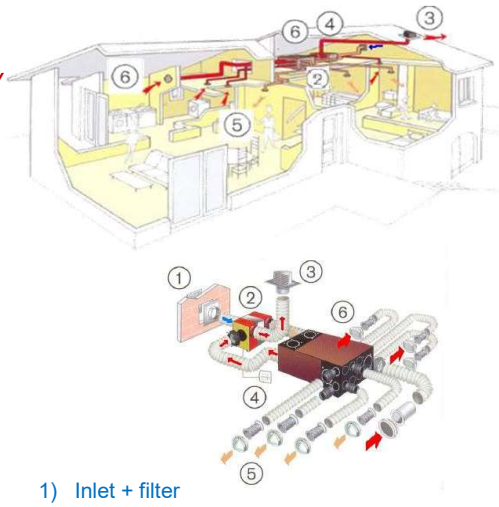
- Air flow control
- Possibility of integration with natural ventilation
- Independence from inconstant weather factors or random occupant behavior
- Adaptability to seasonal climatic conditions
- Limitation of ambient noise
- Control of air speed in the environment

Cons:

- Cost of the plant and its operation
- Impossibility to control the quality of fresh air
- Energy loss in the cold season
- Intake of too hot air in summer

Mechanical ventilation – Dual flow

- *A dual-flow system mechanically provides both supply and return air to the room.*
- Extraction is the same as for single flow systems.
- The inlet is also made through ducts and vents in a separate circuit from the previous one.
- The inlet and outlet flows are coordinated by a control system



1) Inlet + filter
2) Fan
3) Roof extraction
4) Heat exchanger
5) Inlet points
6) Outlet points

Mechanical ventilation – Dual flow

In more complex systems, it is possible to handle the fresh air before it is introduced into the environment, i.e. filter it, cool it or heat it, humidify it or dehumidify it. Finally, with dual-flow systems, energy recovery is also possible of the exhaust air through heat recovery units.

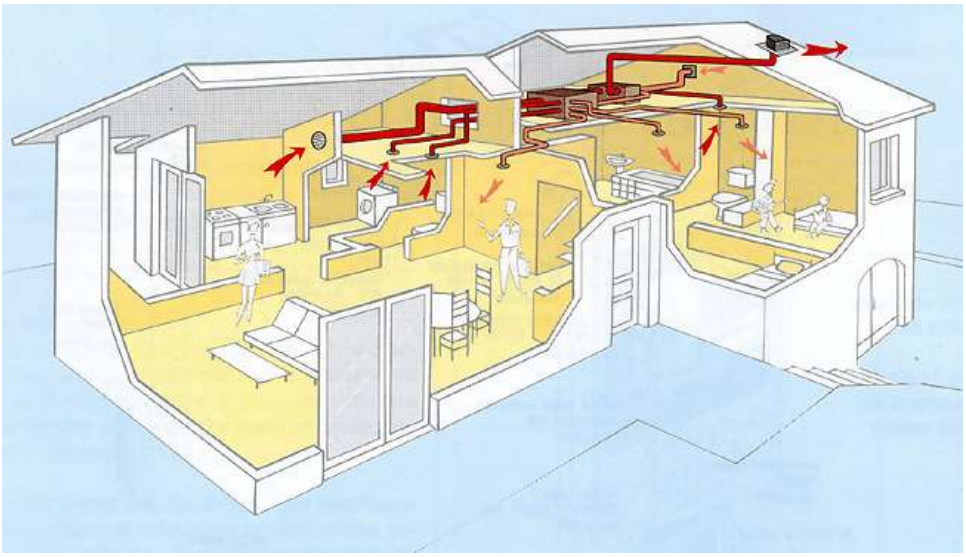
Pro:

- Air flow control
- Possibility to combine a heat recovery unit
- Possibility of integration with natural ventilation
- Independence from inconstant meteorological factors or random behaviors of the occupants
- Adaptability to seasonal climatic conditions
- Limitation of noise in the environment
- Control of air speed in the room
- Control of fresh air quality

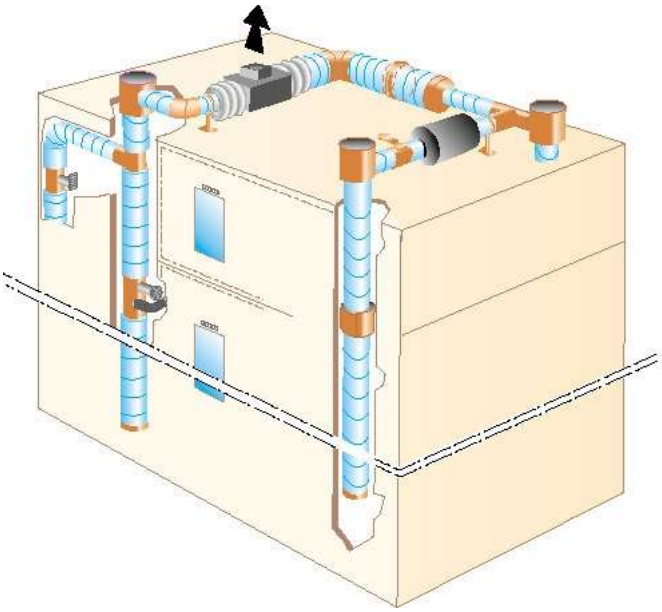
Cons:

- Costs

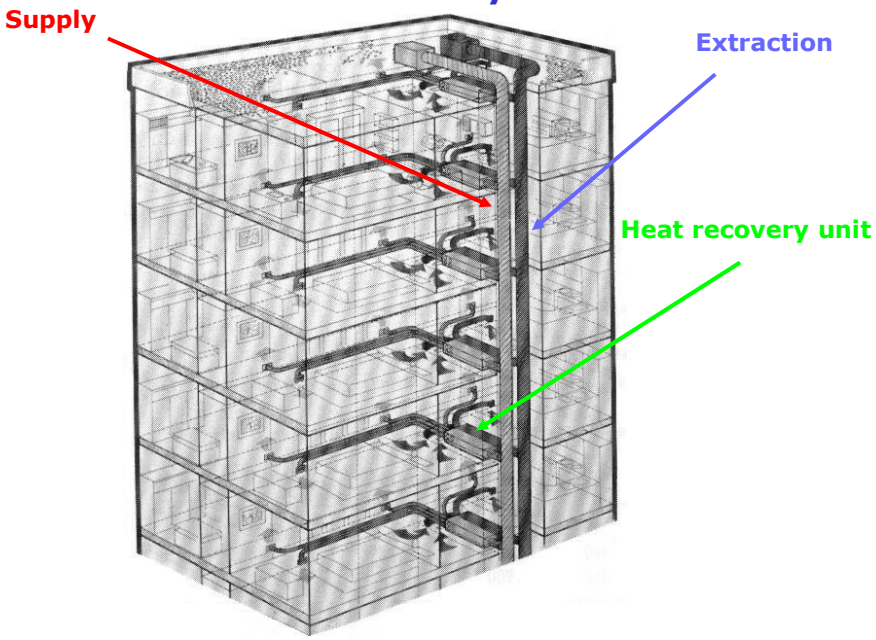
Single-family dual-flow ventilation with heat recovery



Single Flow Ventilation in Apartment block

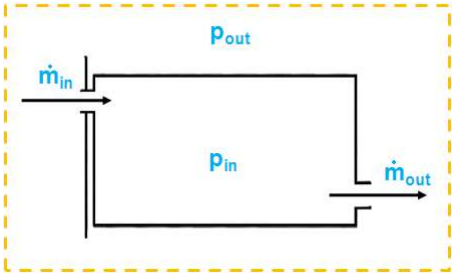


Dual-Flow Ventilation in Apartment block with heat recovery



Mechanical ventilation - local conditions

Pressurized room	If you want to prevent air from entering you create an overpressure	$p_{in} > p_{out}$ $m_{in} > m_{out}$
De-pressurized room	If you want to prevent the air from escaping you create a depression	$p_{in} < p_{out}$ $m_{in} < m_{out}$



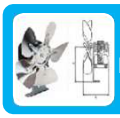
FANS

- Fans force air into (out of) the interior (exterior) of the building
- They can be placed in false ceilings, in the attic or outside the building.


On the roof


Axial fan

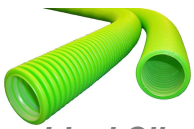

Centrifugal fan


Low flow axial fan


Low flow compact axial fan

Ducts and tubes for forced ventilation

- Ventilation ducts and pipes are spiral galvanized sheet metal ducts of variable diameter designed to convey fresh air inside the room and stale air outside.
- In case of narrow cavities (in the case of renovations) oval ducts can be used, obtained through a process of crushing the circular model.
- In the connection sections of the outlets with the main network flexible channels are used, usually also in galvanized steel.

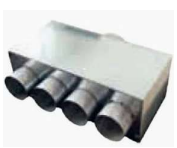

Ideal Clima


Arieggiare


Valsir


Ecoclima


Mitsubishi Electric


IRSAP

Cloth filters

- They consist of a mesh of fibers whose dimensions are much smaller than the distances between them (so that the airflow is not greatly disturbed by the filter). The depth of the filter is much greater than the size of the particles, which are therefore forced to take a long and tortuous route through the filter.
- The air flow passes through the filter fibers and, solid particles with a diameter larger than the distance between the fibers constituting the filter, are stopped exactly as it happens through a sieve (sieve filtration mechanism). Smaller particles, on the other hand, are fixed along the filter fibers by elementary electrical forces.

Flat Panel

With rigid pockets

With floppy pockets

Roller

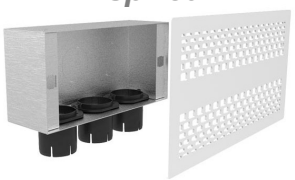
Inlet vents

- The penetration of the inlet jet depends on the inlet velocity and the inlet area.
- The higher the input speed and the higher the velocity, the more penetrating the jet is
- In CMV the through is not usually a problem

Ideal Clima

Ecoclima

Aspiredil



Soler & Palau

Supply air vents

- Self-adjustable: they are equipped with deformable PVC membranes that modify the passage section; they are sized to introduce in the rooms the same quantity of air that is extracted from the services to make up for the internal depression.
- Adjustable: they are equipped with a humidity sensor directly connected to a calibration damper (if humidity tends to fall, the device limits the air flow, maintaining a minimum value); they must be installed in the main rooms of the house (bedrooms, living room) in order to create a wash in the direction of the technical compartments.

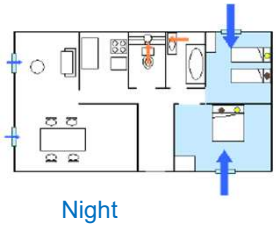
They can be installed on the upper part of the box or frame and on the window frame; they are of the linear type made of plastic and equipped with soundproofing.

Outlet air vents

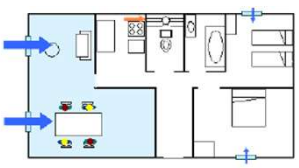
Self-adjustable: they are made of PVC and have, at the center, a self-adjustable regulating device consisting of a rubber membrane that modifies the air passage section according to the pressure it is subjected to.

Hygro-controlled: made of PVC, they have a humidity sensor in the center and a membrane capable of regulating the amount of extraction air according to humidity; it works for pressure differences between 70-130 Pa.

The total ventilation rate calculated for the sleeping area is extracted from the wall vents in the bathroom, while the ventilation rate for the living area is extracted from the wall vent in the kitchen.

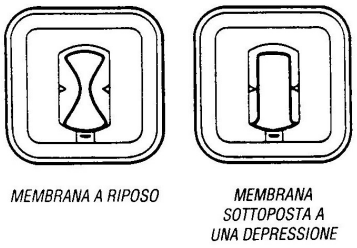


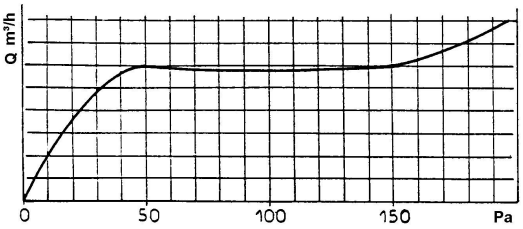
Night



Day

Example





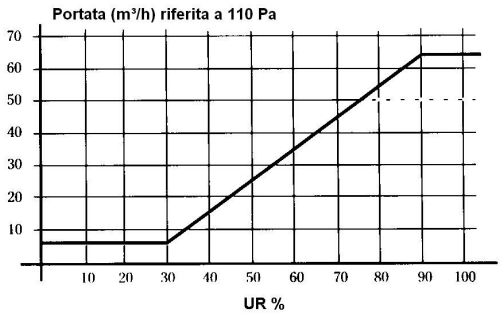
Diagram

Self-adjustable air vents

In winter in the coldest periods there is still entrance from infiltration (not perfectly sealed envelope) because of the large internal-external Δt which causes large internal-external Δp.

The sealing aspect of the envelope is all the more important the colder the winter climate.

Example



Hygro-controlled

Presence of a hygroscopic element that opens or closes the vent depending on the RH in the room.

It can be installed for inlet (more frequent or for expulsion)

It can provide variable flow rate (different ventilation needs in presence/absence of people in residential). A variable speed fan is needed.

In case of high infiltration in cold periods the relative humidity drops and therefore the vents limit the air entering the room.

Examples

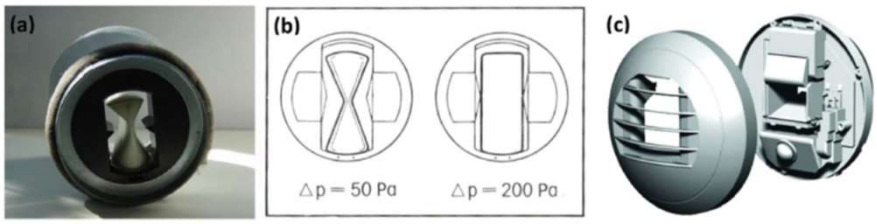
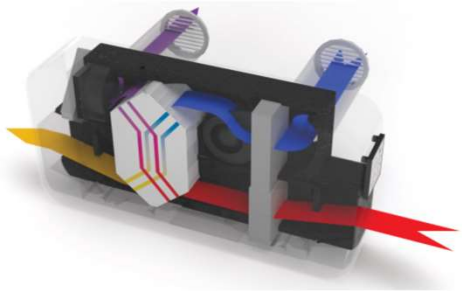


Fig. 1. (a, b): Constant flow extract unit with auto-adjustable silicon membrane [source: Aldes]; (c): Hygro-adjustable extract unit [source: Ecoclima].

Dual flow decentralized solutions



Pros

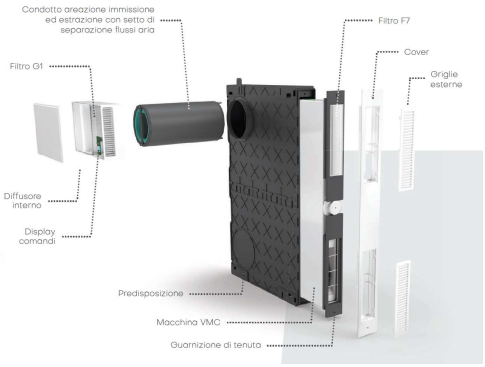
- No ducts
- Easy to install
- Easy to maintain

Cons

- Several holes on the outer walls
- No possibility to handle the air entering the room

Helty

Dual flow decentralized solutions



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Alternate Flow Decentralized Solutions

This simplified system consists of machines that half the time extract and half the time introduce air from the same duct.

Heat recovery is limited, no special filtration is provided.

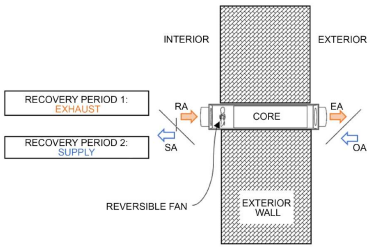

Fig. 23 Single-Core Fixed-Bed Regenerator