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# Design and Installation Guide of Passive Stack Ventilation Systems in Retrofitted Apartment Buildings

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## SYNOPSIS

Almost 60% of French residential buildings were built before the seventies, and an important part of those is to be retrofitted for complying with new needs with regard to acoustic insulation and energy saving.

Retrofitting modifies the airtightness of the building envelope and can lead to an insufficient air change rate in passive stack ventilated buildings ; the existing ventilation system has therefore to be redesigned in order to insure adequate indoor air quality.

Dimensioning of the stack effect ventilation system for multi-storey dwellings is a critical issue, as the air flow rate depends on many parameters as outdoor temperature, wind, distribution of air inlets and envelope air leakages, ducts area and length, characteristics of outlets and cowls.

Research work has been initiated by the CSTB, GDF and SOCOTEC (commissioning authority) to produce a design and installation guide of ventilation system and flue system for gas appliances by passive stack effect in apartment buildings. The guide is aims at helping engineers, building consultants and professional building owners to properly choose and dimension the ventilation system based on general and continuous air renewal.

Results of this research work and main features of the guide are presented in the paper, in a first part the suitable system design is given according to the typology of the existing building and the different measures to be taken are listed. The choice and dimensioning of ventilation components are operated in order to comply with indoor air quality requirements. Dimensioning was derived from simulation results obtained by a numerical model developed at CSTB, predicting the ventilation rates, which has been described in the 15th AIVC Conference paper. The dimensioning of the ventilation system depends on the stack height and section area of ducts.

The guide also deals with requirements and specifications concerning gas appliances, schedule of operation conditions of renovation work taking into account personal protection during this work, installation, commissioning and maintenance, use instructions for the occupants and building managers.

## LIST OF SYMBOL

| | |
|---|---|
| St | sum of exhaust ducts cross sectional areas ($cm^2$) |
| n1 | height between the highest floor of the group of dwellings and the cowl (number of floors) |
| n2 | number of floors served by the same group of ducts (if individual ducts n2=1) |
| n | number of habitable rooms in the dwelling (the living room is taken as two rooms) |
| np | number of habitable rooms in the group of dwellings (np = n2 x n) |
| C | suction coefficient of the cowl |
| $\zeta_c$ | pressure drop coefficient of the cowl |

# 1. - INTRODUCTION

In the French apartment building stock two thirds of buildings were constructed before 1971. A third of the existing apartment building stock is composed of dwellings without ventilation system, another third with passive stack ventilation system. The apartment building stock is in need of renovation for various reasons : refurbishment of interiors, creation of new service rooms, retrofitting of heating installation, replacement of windows, insulation of façades,...

Today, retrofitting measures represents a significant proportion of the total construction market and concern a lot of passive stack ventilated existing buildings. Energy saving measures make the building envelope so airtight that hygro-thermal behaviour of the building can be completely modified and ventilation operation can be disrupt. Attention must be paid to attaining an acceptable air quality in dwellings by ensuring a minimum ventilation rate.

The renovation measures (in particular airtightness measures) often modify the state of ventilation so much that the requirements with regard to indoor air quality, comfort, security and risk of moisture damage do not meet anymore. Thus the ventilation shall be carefully considered when selecting renovation measures. A new ventilation system has to be designed, reusing the existent ducts in order to comply with indoor air quality, comfort and security requirements.

In order to assist engineers and building professionals owners and building consultants in obtaining a satisfactory ventilation system, a guide has been produced [1].

A CSTB's numerical model [2] was adapted and used to perform numerous simulations for dimensioning the ventilation system (more than one thousand runs). Recommendations based on a simplified description of the existing building were derived from this work.

The guide gives practical solutions which can be achieved from a typology of the existing dwellings and installations.

# 2. - TYPOLOGY

Right from the beginning of the century, French regulations have been the mover of the technological progress in ventilation and the present state of ventilation in France is the result of a long sequence of habits and requirements [3]. The following typology of existing apartments can be done according to the date of completion of buildings.

**before 1906** : no regulation on flue or ventilation systems ; dwellings can be without any chimney.

**from 1907 to 1937** : Individual flue system is required in the kitchen and in each habitable room of the dwelling. No regulation on ventilation : airing by window opening, by air leakage of the building envelope and by flues.

**from 1937 to 1955** : Individual flue system is required in the kitchen and in each habitable room of the dwelling. Continuous ventilation of the toilet is required.

**from 1955 to 1958** : Shunt duct is allowed for exhaust combustion products and polluted air in service rooms.

**from 1958 to 1969** : Individual or collective flue system is required in the kitchen and only one flue system is required for three habitable rooms. Ventilation operates room by room : the habitable rooms are ventilated by infiltration and exfiltration through the envelope, the kitchen

by a chimney and/or ventilation duct, the bathroom and toilets by two ventilation ducts in lower and higher locations.

**from 1969 to 1982** : No more requirement about flue system. General and continuous ventilation is required. Fresh air enters habitable rooms via air inlets and polluted air exhausts from service rooms via exhaust vents. Two systems can be used : passive stack ventilation or mechanical exhaust.

**since 1982** : General and continuous ventilation principle remains but the ventilation rate is modified.

## 3. - GENERAL APPROACH

Ventilation strategy applied to retrofitted dwellings is the general and permanent ventilation with air flow route control. Fresh air is distributed in habitable rooms and polluted air is expelled from service rooms through the exhaust vents : air circulates from the least polluted rooms to the most ones. The guide is intended to provide solutions as easy as possible with dimensioning calculations reduced to the essential. It is applied to the ventilation systems and flue systems of gas appliances operating by passive stack effect in apartment buildings. Passive stack ventilation is achieved by using the former flues as ventilation ducts as far as possible.

Each stage from design ventilation system up to maintenance via achievement is described in the guide (cf. figure 1). At the design stage, the technical solutions to be implemented from the existing building typology, the choice and the dimensioning of ventilation components are given in the guide. The design of ventilation system requires a prerequisite diagnosis of the installation and a consistent choice of components. At the realization stage, the guide explains how to implement the different ventilation components and operate the renovation work taking into account personal protection. The last part of the guide deals with commissioning, maintenance and use instructions for the occupants and building managers.

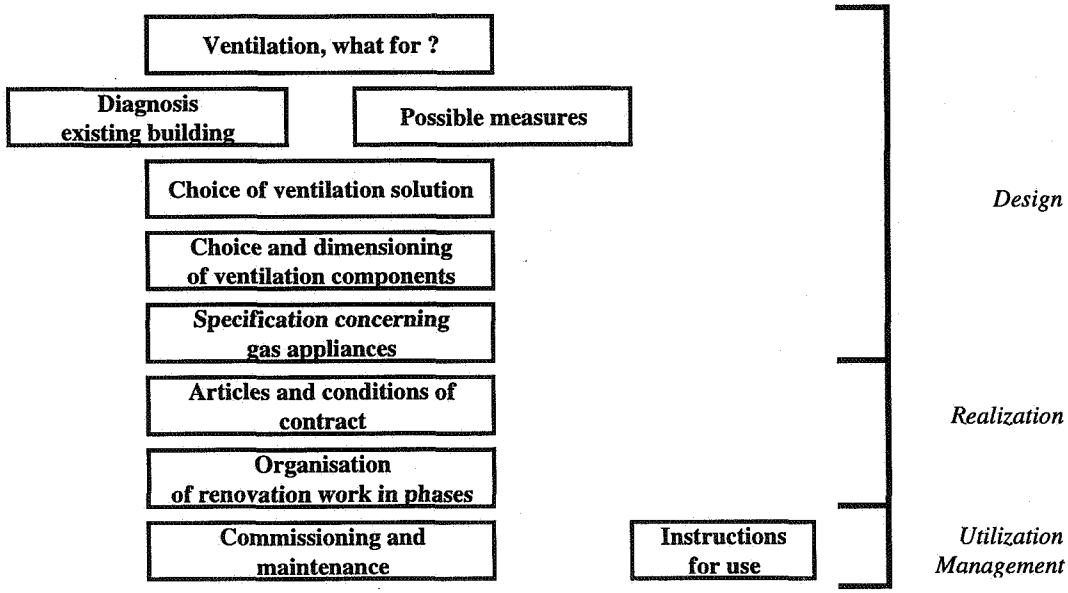


**Figure 1: different stages in renovation work**

## 4. - DIMENSIONING CALCULATION

Each component of the ventilation system has to be properly dimensioned in order to obtain satisfactory ventilation.

To make the work easier for the guide users the area values of the air inlets, the inter-rooms openings and the air outlets to be used are directly given in the guide and are the same for all the dwellings ; to limit the energy losses due to ventilation, the designer can choose self-regulated or humidity-controlled outlets instead of fixed outlets.

**inlets :** one self regulated inlet in each habitable room ; equivalent area 30 $cm^2$ (the living room is taken as two rooms).

**inter rooms openings :** kitchen door 160 $cm^2$, other doors 80 $cm^2$.

**outlets :** in the kitchen, a gas boiler is connected to a flue ; equivalent area 120 $cm^2$ in toilets and bathroom one outlet grille; equivalent area 75 to 150 $cm^2$ with possibility of self regulated or humidity controlled outlet for saving energy (all the outlets grilles mounted in the building are the very same).

In France, in buildings built after 1906 ducts exist : consequently there is no, strictly speaking, need to design and dimension the ducts ; however section area and height of ducts have to be considered in this design stage.

Extract flow rate depends on the sum of exhaust ducts cross sectional areas (**St** in $cm^2$) divided by the number of habitable rooms in the group of dwellings (**np.n2**) and the height of air column between the highest floor of the group of dwellings and the cowl (**n1** given in number of floors).

The solutions given in the guide comply with the ventilation requirements in terms of minimal exhaust flow rates during the most part of the heating period. Six different ventilation systems (depending on characteristics of outlets and cowls) are taken into account :

**system 1 :** fixed exhaust grilles and cowl class B
(French standard P 50-413 : $\zeta_C \leq 2$ and $C \leq -0.65$).

**system 2 :** self regulated outlet or humidity controlled outlet and cowl class B

**system 3 :** fixed exhaust grilles and motorised cowl class B
(these cowls are motorised and can give an additional pressure of 15 pascals when necessary).

**system 4 :** self regulated outlet or humidity controlled outlet and motorised cowl class B

**system 5 :** fixed exhaust grilles and two speeds motorised cowl class B
(these cowls are motorised and can give an additional pressure of 15 pascals when outdoor conditions are insufficient and an additional pressure of 35 pascals during cooking time).

**system 6 :** self regulated outlets or humidity controlled outlets and two speeds motorised cowl class B.

An example of solutions for collective ducts is given in figure 2.

**n1 from 0 to 3**

| | System | | | | | |
|---|---|---|---|---|---|---|
| St / np n2 | 1 | 2 | 3 | 4 | 5 | 6 |
| < 20 | | | -5°C | -5°C | -5°C | -5°C |
| [ 20 to 25 [ | | | 0°C | 0°C | 0°C | 0°C |
| [ 25 to 30 [ | | | 4°C | 4°C | 4°C | 4°C |
| [ 30 to 35 [ | | | 8°C | 8°C | 8°C | 8°C |
| [ 35 to 40 [ | | | 12°C | 12°C | 12°C | 12°C |
| [ 40 to 45 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 45 to 50 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 50 to 70 [ | | | 16°C | 16°C | 16°C | 16°C |
| ≥ 70 | | | 16°C | 16°C | 16°C | 16°C |

**n1 7 and more**

| | System | | | | | |
|---|---|---|---|---|---|---|
| St / np n2 | 1 | 2 | 3 | 4 | 5 | 6 |
| < 20 | | | 8°C | 8°C | 8°C | 8°C |
| [ 20 to 25 [ | | | 12°C | 12°C | 12°C | 12°C |
| [ 25 to 30 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 30 to 35 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 35 to 40 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 40 to 45 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 45 to 50 [ | | | 16°C | 16°C | 16°C | 16°C |
| [ 50 to 70 [ | | | 16°C | 16°C | 16°C | 16°C |
| ≥ 70 | | | 16°C | 16°C | 16°C | 16°C |

**In each box you find the outdoor temperature at which the motorised cowl interlocks.**

**not recommended** inadequate air quality

**acceptable** acceptable air quality or
adequate air quality but immoderate energy losses

**recommended** adequate air quality
without immoderate energy losses

**Figure 2: Example of exhaust ventilation system dimensioning**

# 5. - ACHIEVEMENT AND GUIDELINES

## 5.1 - Diagnosis

This chapter of the guide gives the check list of the parameters to be taken into account :

- year of construction of the building,

- existing ducts (number, state - air tightness, emptiness -, location, ...)

- existing cowls (characteristics, location on the roof)

- gas equipment

- reusable ventilation equipments (inlets, transfer grilles, outlets, ...)

## 5.2 - Conditions of contract

This chapter describes who does what and indicates the documents to be produced by the parties involved.

## 5.3 - Organisation of renovation work in phases

The objective is to insure the security of the occupant during the work ; the chapter gives the sequential organisation of the work :

- put the ducts to rights,

- take up the old outlets,

- put in the new outlets,

- connect the gas appliances,

- change windows (possibly),

- put in the inlets in main rooms,

- put in the inter room openings,

- take up the inlets in the service rooms and stop up the openings,

- carry out the self inspection check list.

## 5.4 - Commissioning and maintenance

This chapter gives directions for use addressed to for users and managers.

# 6. - EXAMPLE OF APPLICATION

## 6.1 - Description of the building

Five storey building built in 1958.

Kitchen with inlet grille (VG) and smoke flue (SF) ; bathroom and toilets with windows.

One smoke flue in the living room (not used)

All the smoke flues are shunt type flue systems (collector 20 x 20 cm)

## 6.2 - Propounded solution

The two smoke flues are in good state : they can be reused

The bathroom and toilet will be linked with an horizontal duct to the living room smoke flue which becomes a ventilation duct (VD).

Data of the problem :

- n2 = 5  n1 = 0.
- St = 2 x (20x20) = 800 $cm^2$
- 3 principal rooms : np = 3 +1 = 4
- St / np n2 = 40

**It is not necessary to use motorised cowls (see table figure 2) if an acceptable solution is provided for but a motorised cowl can be used, interlocked at 12°C outdoor temperature for a better air quality.**

**Inlets, inter-room openings and outlets are dimensioned according to paragraph 4**

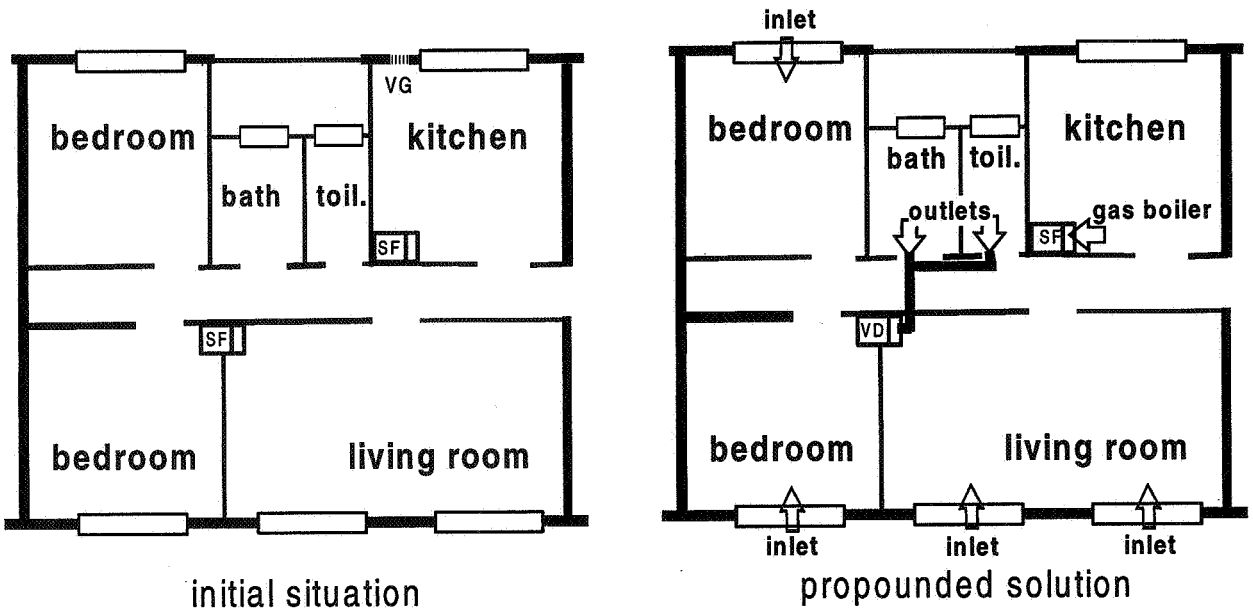


**figure 3 : dwelling before and after retrofitting**

## 7. - CONCLUSION

A methodology to design and achieve passive stack ventilation systems for retrofitted apartment buildings was developed and led up to the production of a guide. The guide which was issued in April 95 meets success because it fulfils requirements of engineers and consultants. Indeed, before its issuing there was no practical document to assist the building professionals in achieving proper passive stack ventilation. The technical solutions given in the guide involve ventilation components available on the French market. Nevertheless, the main features of this guide could be applied in other countries considering national building typologies, requirements and habits.

## ACKNOWLEDGEMENTS

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