Inspection of ventilation systems – summary of existing protocols and technical survey

Nolwenn Hurel[1*], Valérie Leprince[2]

1 PLEIAQ
2 Avenue de Mérande
73 000 Chambéry, France
**Corresponding author: nolwenn.hurel@pleiaq.net*

2 PLEIAQ
84 C Avenue de la Libération
69330 Meyzieu, France

ABSTRACT

In a context of energy use reduction, low energy buildings are becoming more widespread. This kind of construction requires a good envelop airtightness to prevent uncontrolled leakages of conditioned air leading to energy losses. As a result, more and more ventilation systems are installed to ensure a sufficient air change rate for a good indoor air quality.
However, in practice many issues are found with the installed ventilation systems not providing the expected flowrates. More and more countries have a mandatory inspection of ventilation systems, such as Sweden, Ireland and Germany, or France (since January 2022).
This paper aims at comparing the various approaches to help provide guidelines on the inspection of ventilation systems. A general summary is first presented based on an EPBD feasibility study detailing 20 protocols from 9 countries, completed with the new Irish protocol. It presents the types of protocols (mandatory or not) per country; the types of buildings controlled (residential only or not); the aspects covered by the inspection; who is allowed to perform it and its periodicity.
Technical details collected through a 21 question survey are then given for 5 protocols implemented in Sweden, Belgium, Ireland, France and USA. A wide range of issues are investigated, including the preparation of the building before the measurement; the possibility to measure the flowrate inside the ductwork; the way to address various practical difficulties for measurements at air terminal devices; requirements on measuring devices, their uncertainty and calibration; what is considered as non-conformities and their consequences; etc.

KEYWORDS

Please provide a maximum of five keywords which reflect the content of the paper

1 INTRODUCTION

In a context of energy use reduction, low energy buildings are becoming more widespread. This kind of construction require a good envelop airtightness to prevent uncontrolled leakages of conditioned air leading to energy losses. As a result, more and more ventilation systems are installed to ensure a sufficient air change rate for a good indoor air quality.
However, in practice many issues are found with the installed ventilation systems not providing the expected flowrates. In France a study on 1287 dwellings showed that 68% do not meet the regulation (Jobert and Guyot, 2013). More and more countries have a mandatory inspection of ventilation systems, such as Sweden, Ireland and Germany, or France (since January 2022).
This report aims at comparing the various approaches to help provide guidelines on the inspection of ventilation systems. It is based on an EPBD feasibility study detailing 20 protocols from 9 countries (Durier et al., 2019) with the addition of the new guide to comply with Irish regulations and a survey addressed to various countries for technical details.
We would like to thank the respondents to this survey: Iain Walker (LBNL) in the USA, Maarten De Strycker (BCCA) in Belgium, Simon Jones (Aereco Ltd) in Ireland, Olof Nevenius (Funktionskontroll-anterna i Sverige) in Sweden and Ariane Lesage (Cerema) in France.

2 SUMMARY OF EXISTING PROTOCOLS FOR THE INSPECTION OF VENTILATION SYSTEMS

2.1 Data

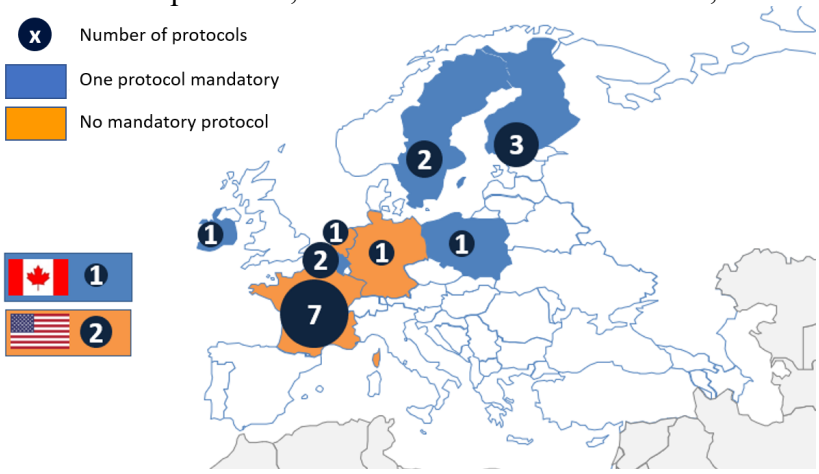
The main reference for this summary of existing protocols for the inspection of ventilation systems is the feasibility study conducted for the European Commission to follow the article 19a of the EPBD Directive 2018/844/EU, and more precisely the report of the Task 1 "Review of regulations, guidelines and standards on the inspection of stand-alone ventilation systems." led by INIVE (Durier et al., 2019). This study is gathering and detailing 20 protocols from 9 countries.
As an additional reference, the new guide to comply with Irish regulation (Part F) is also included (Department of Housing, Planning and Local Government, 2019).
The detailed list of the 21 protocols for the inspection of ventilation systems from 10 countries which are summarized in this section are listed in Annex 1.

2.2 Types of protocols

Only six countries have a mandatory protocol (by legislation or regulation): Poland, Belgium (in Flanders only), Finland, Ireland, Sweden and Canada. The other 15 protocols are mostly non-mandatory guidelines (13) and two standards from France and the USA.

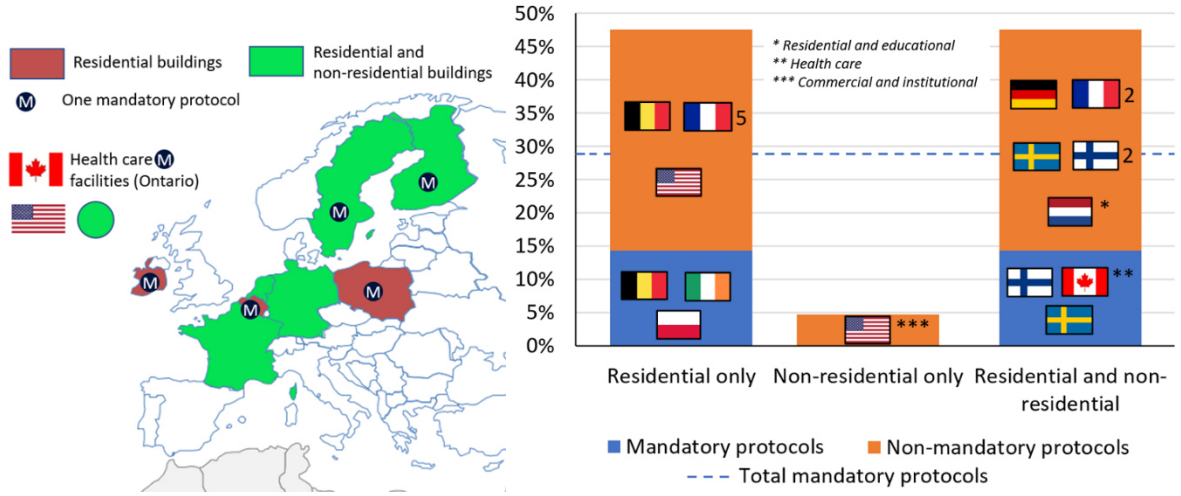
2.3 Countries

Some countries have several protocols, with a maximum of 7 in France, as illustrated bellow:



2.4 Type of buildings

Half of the mandatory protocols (3) and almost half of the non-mandory ones (7) are dedicated to residential buildings only, while the other half is for both residential and non-residential buildings. There is only one protocol, in the USA, that does not include residential buildings and is dedicated to commercial and institutional buildings only. In this country, the other protocol applies to apartments only when each of them has its own/independent ventilation system.
The Canadian protocol is aimed for health care buildings only, that is to say hospitals, laboratories, psychiatric and mental health service facilities, long-term care homes and residences for persons with developmental or physical disabilities.
In Netherlands, the non-commercial buildings covered by the one protocol are only the educational ones.

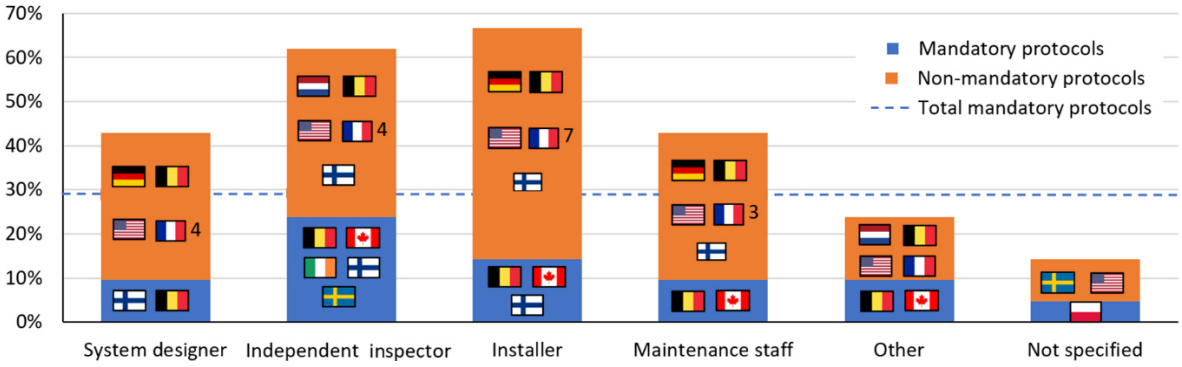


2.5 Inspection

Who is allowed to perform the inspection?

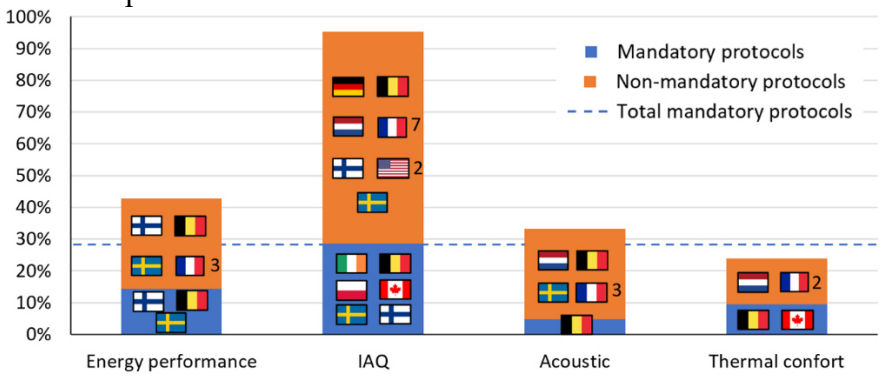
Among the mandatory protocols, there is only in Poland that has no specification about who can operate the inspection. All other mandatory protocols allow or require (in Ireland and Sweden) an independent inspector. In Flanders, the inspection can be performed by all actors but independent auditors from a national certification organization control inspectors.

Non-mandatory protocols are overall more flexible on who is performing the inspection, with in particular most of them (11 out of 15) allowing the installer to control.



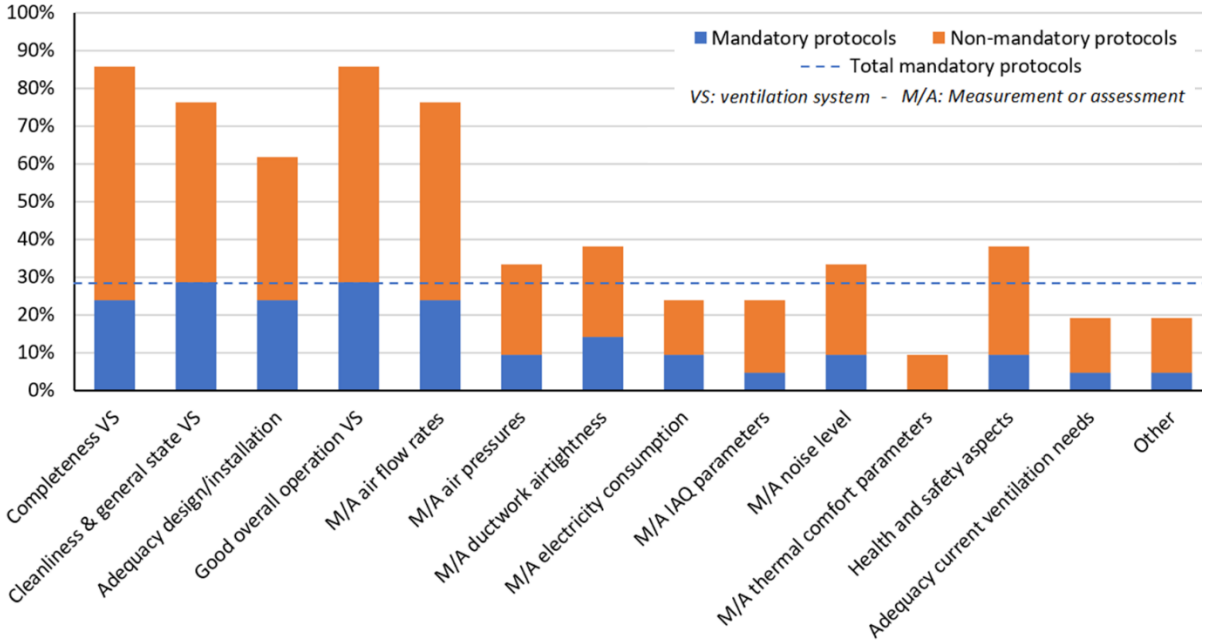
What types of control are performed?

All protocols cover the indoor air quality (IAQ) aspect, except one in Finland; less than half of them cover the energy performance and/or the acoustic performance, and a quarter only cover the thermal comfort aspect.



Aspects covered by the inspection

Most protocols cover a wide range of aspects as illustrated below. For example, all mandatory protocols cover the control of cleanliness, general state and good overall operation of the ventilation system (VS), and more than half of all protocols cover also the completeness of the VS, the adequacy between design and installation and a measurement or assessment of the air flow rates.

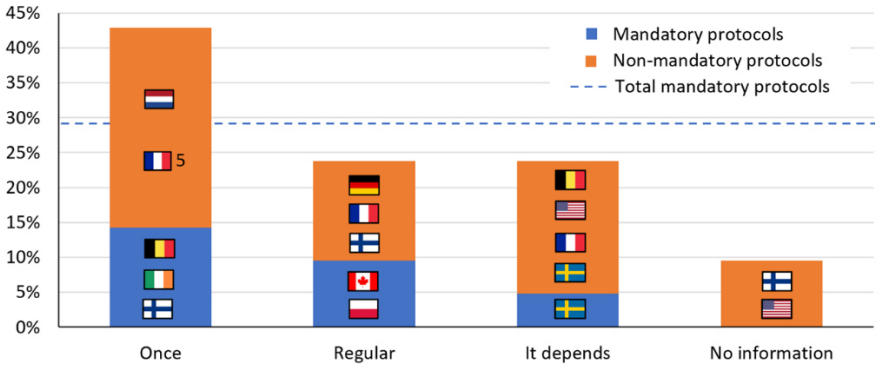


Periodicity of inspection

About half of the protocols (mandatory or not) are intended for a single inspection.
For the other half, concerning mandatory protocols:

- in Poland it is required to have an inspection at least every 5 years,
- in the Ontario State since the protocol is for health care facilities a periodicity of 6 months is required,
- in Sweden it depends on the type of buildings:
    - every 3 years for day-care centers, schools etc. with all types of ventilation; blocks of flats, office buildings etc. with balanced ventilation
    - every 6 years for blocks of flats, office buildings etc. with mechanical exhaust and natural ventilation;
    - single inspection for one and two-dwellings houses with mechanical exhaust with exchanger ventilation and balanced ventilation.

In Belgium, for the non-mandatory protocol the guide proposes different inspection frequencies from 1 month to 3 year-intervals depending on the type of components: 1 month for filters, 3 months for the natural openings, air intakes, exhaust devices, 1 year for heat exchangers and fans, 3 years for ducts.



3 TECHNICAL QUESTIONS - SURVEY

3.1 Details of the 5 protocols

A survey of 21 technical questions was sent in the 10 countries were a protocol for the inspection of ventilation systems is known to exist. The objective was to get to know better how specific technical issues are handled for the inspection of ventilation systems according to the various protocols.
5 answers were collected from 5 countries: Belgium, Ireland and Sweden for their mandatory protocols, France for the non-mandatory protocol "Promevent" and USA for the non-mandatory protocol for residential buildings.

Note: In the illustrations of this section 3, the flags have black edges for the countries with mandatory protocols and white edges for non-mandatory protocols.

3.2 Flowrate measurement protocol

Who is in general doing the measurement?

In the summary of the existing protocols section 2, a graph is illustrating who is allowed to perform the inspection (paragraph 0) but does not indicate who in practice is usually doing it.
In Ireland, and Sweden an independent inspector is required. In the USA the protocol is mostly used by energy raters, but has been written for use by a wider audience. In Belgium the inspection is more often performed by the installer but also an independent inspector (EPB-reporter) is very common. In France, nobody in particular is appointed to do the measurement, it can be the installer, independent inspector, maintenance staff or system designer. However, in the context of the Effinergie Label it has to be an accredited independent inspector.

What are the preparations for the building before the measurements?

Interior doors:

Ventilation openings:

Concerning the preparation of the building before the measurements, the respondent from Sweden did not specify about the opening of interior doors and sealing of ventilation openings in his answer. For the other protocols, the interior doors must be closed for all but the US one and all trickle-vents must stay open (in France they cannot be closable).
Other specifications are required depending on the protocols:

- USA:
    - Supply registers and return grilles: left as is

    - Balancing dampers: left as is
    - Zone dampers: left as is, or kept open if interconnected with a Forced-Air System
    - Vented combustion appliances: switched off or in “pilot only” mode
    - Fan of forced-Air System: if part of the ventilation system, switched on in “Fan” mode and checked; otherwise switched off
    - Ventilation system (local/central): switched on
    - Other Fans: switched off
- Belgium:
    - All systems interacting with outdoor air: switched off
    - Clean building (especially dust free)
    - All components in the system set to nominal flow
    - Clean and new filters
    - DCV: switched off (sensors overruled to nominal position of the flow)
    - Building should be in such conditions that measurement can be done with pre- and postheating switched off
- Sweden: Building activities are ended
- France:
    - Make the functional checks of the system prior to measurements (kind of ATD, fan switched on, etc…)
    - The settings at ventilation unit and at the ATDs must be saved and unchanged during the measurements

Are there requirements on the opening of windows and outer doors during flowrate measurements?

In Ireland, France and Belgium, the windows must be closed during the flowrate measurements.
In Sweden the windows must be closed during all measurements but open when they measure the forced higher airflow for hoods over hotplates in the kitchen and exhaust air vents in bathrooms with bathtubs or showers without windows to open during shower periods.
In the USA, specific flowrate measurements can be carried out with interior doors or windows opened in order to identify potential problems on internally mounted air transfer devices, and to check the balancing.

Is there a minimum duration for the flowrate measurement or a constraint on the stability of the flow?

In the USA the constraint is 10 second averaging. With however the exception of bag filling with a duration determined by the flow and bag size (3 measurements are required that are within 20% of each other).
In France the flowrate measurement must last at least 10 seconds.
In Belgium the minimum duration of the total measurement of the building is 20 minutes but there is no constraint on an individual ATD.

Is the flowrate measurement inside the ductwork an option?

The flowrate measurement inside the ductwork is an option for all protocols but the Irish one.
In the USA, there are limitations on distances to upstream and downstream fittings as specified by the instrument manufacturer.

In Belgium specific conditions for the ductwork measurement should be respected: e.g. minimum straight length of the duct before and after. In practice it is only performed if measurement of ATD is not possible.
In Sweden, according to the regulations, flows must be measured in all branches of the systems.

Is the actual power consumption of the fan measured? And how?

The actual power consumption of the fan is not measured for all protocols but the Belgium one. For this country, it is measured in at least 2/3 of the measurements. There are legal requirements on the measurement device (precision and calibration). It is mostly done with a quite simple plug and socket device.
In Sweden only rated currents are noted, the controller is not trained to measure electricity.

Is the Demand Control Ventilation (DCV) system evaluated? And how?

The DCV system is evaluated for all protocols but the American one.
In Belgium there exists checklists for "certified" systems. Checklist include check of brand and model of DCV-system, correct position, connection and type of sensors, correct position of ATD. Certified systems have passed a laboratory check on the functioning.
In Ireland they are evaluated shortly through agreement certificate; in Sweden based on the set criteria and in France by checking if the different levels are well-functioning and by measuring airflows at min and max when it is possible.

Is the acoustic performance of the system evaluated?

The acoustic performance of the system is evaluated only with the Swedish protocol, by measurement when during the inspection it is suspected that the regulatory requirements are exceeded.
In the USA acoustic performance is covered by ASHRAE 62.2 and uses laboratory tests, not field tests.
In Belgium, acoustic evaluation is not mandatory. Evaluation method exists, based on measurement or calculation.
In France acoustic defaults should be underlined in the report, but the acoustic performance is not evaluated.

3.3 Measurement at ATD (air terminal devices)

What is done when the ATD is installed in a way preventing from positioning airtightly the measuring device on the wall behind?
In the USA, the protocol does not address this issue directly, but it allows several alternative approaches including in-duct measurement.
In Belgium they use ductwork measurement, or other solution from set of allowed solutions for measurement. Otherwise, they report “not measurable” (= 0m³/h).
In Ireland the issue is noted in report, not dealt with specifically.
In Sweden measurements are then made in the duct or with a "hook" in the device.
In France, airflow measurement is not possible in this case: measurement is not valid. If a pressure measurement can be done instead, this can be a solution: then one should make sure that the measuring device is adapted to the type of ATD.

What is done when the measuring device cannot cover the ATD?
The answers to this question are very similar to the previous ones.
In the USA, the protocol does not address this directly, but it allows several alternative approaches including in-duct measurement. The measuring device must cover the ATD because it requires ".... an airtight perimeter seal around the inlet terminal."
In Belgium they use ductwork measurement, or other solution from set of allowed solutions for measurement. Otherwise, they report “not measurable” (= 0m³/h).
In Ireland the issue is noted in report, not dealt with specifically.
In Sweden measurements are then made in the duct or with a "hook" in the device.
In France, airflow measurement is not possible in this case: measurement is not valid. If a pressure measurement can be done instead, this can be a solution: then one should make sure that the measuring device is adapted to the type of ATD.

What is done when the ATD cannot be centred in the measuring device?
In the USA, no direction is given for this issue.
In Belgium, this is not a requirement in the protocol, centring is only an advice.
In Ireland the issue is noted in report, not dealt with specifically.
In Sweden measurements are then made in the duct or with a "hook" in the device.
In France, if the ATD cannot be centred but the measuring device can be positioned airtightly and totally covers the ATD, the measurement can be valid.

3.4 Measuring devices

Are there requirements on measuring devices to be used according to the kind of ATD for <u>exhaust</u> systems?

There are requirements on measuring devices according to the kind of ATD for exhaust systems for all protocols but the Swedish one.
In the USA, for an inlet terminal the airflow is permitted to be measured using a Powered Flow Hood, using an Airflow Resistance Device or using a Passive Flow Hood.
In Belgium it is advised to always use stabilisation grid and largest hood, but the measurement is accepted without if the situation makes it not possible.
In France, for humidity sensitive ATD, only pressure measuring devices must be used whereas for the other kinds of ATD, either pressure or airflow measuring devices can be used.

Are there requirements on measuring devices to be used according to the kind of ATD for <u>supply</u> systems?

As for exhaust systems, there are requirements on measuring devices according to the kind of ATD for supply systems for all protocols but the Swedish one.
In the USA, for an outlet terminal, the airflow is permitted to be measured using a Powered Flow Hood or using a Bag Inflation Device.
In Belgium a stabilisation grid is mandatory; it is advised to use largest hood, but the measurement is accepted without if the situation makes it not possible.
In France, for supply systems, only airflow measurements are required with a specific measuring device depending on the kind of ATD:

- pitot tube + powered flow hood: acceptable in all cases,
- propeller anemometer + hood & checked thermal anemometer + hood: acceptable in most cases
- one-point thermal anemometer: not acceptable.

Are there requirements on the uncertainty of measuring devices?

There are requirements on the uncertainty of measuring devices for all protocols. In Belgium it is maximum 15%; in Ireland ± 10%.
In the USA, it depends on the measuring device:

- For a powered and passive flow hoods: 5 percent or 5 cfm (2.5 L/s or 0.0025 m3/s), whichever is greater.
- For in-duct measurements: 10 percent or 5 cfm (2.5 L/s), whichever is greater.
- For pressures: maximum error of 1 percent of reading or 0.25 Pa (0.0010 in. H20), whichever is greater.
- For diagnostic tools integrated into ventilation equipment: the maximum error of the integrated diagnostic tool shall be 15 percent of the highest flow setting of the ventilation equipment.

In Sweden, the dimensional accuracy complies with SS-EN 16211.
In France, requirements on uncertainty for airflow measurement devices are MPE ≤ 10% which corresponds to a total maximum uncertainty = 15%. Requirements on uncertainty for pressure measurement devices are MPE ≤ 3%/0.5 Pa which corresponds to a total maximum uncertainty = 10%/5 Pa.

What is the physical value that is calibrated?

The physical values calibrated are the pressure and the flow for the protocols in Ireland, France and USA.
In Sweden and Belgium, the velocity is also a physical value calibrated.
The Belgium respondent commented that it depends on the manufacturer of the device.

What is the calibration period for measuring devices?
A calibration period is defined in each protocol.
In the USA, all equipment shall have their calibrations checked at the manufacturer's recommended interval and at least annually if no time is specified.
In Belgium it is 2 years; for flow devices and 5 years for power meters; in Ireland and Sweden it is one year and in France it is 2 years for manometers and maximum 4 years for flow hoods.

3.5 Conformity / Non-conformity

How are non-conformities handled?

In Sweden every non-conformity should be corrected. In Ireland also, but it depends on flow rates.
In the USA, the protocol is a method of test not a regulation and does not cover the consequences of not meeting target flows.
In Belgium a table of non-conformities with sanction is available. Some should be corrected, some not.
In France all of the non-conformities should be mentioned in the report or in the grid of inspection, differentiating those that relate to regulation or good practices.

For the <u>dwelling</u> to be conform:

There are two distinct approaches to consider a dwelling to be conform in terms of air flow rates.
On one hand, in France and in Ireland it is the total flowrate that is required to be conform.

On the other hand, for the other protocols (Sweden, USA and Belgium) every ATD shall be conform.
In Sweden requirements for air flows are calculated by a consultant on information from the user and regulatory requirements.

For a <u>non-residential</u> building to be conform:

This question does not apply to the French, Irish and American protocols as they are for inspections in residential buildings only.
The Belgium and Swedish protocols covering also non-residential buildings require for them to be conform that every room shall be conform.
In Sweden requirements for air flows are calculated by a consultant on information from the user and regulatory requirements.

Are there measuring tolerances? Ex: if the measured flowrate is 5% under the required one, is it acceptable? Is the measuring device's uncertainty taken into account?

In Ireland, Sweden and France there are measuring tolerances, but not in Belgium.
In Ireland this tolerance is ± 10%.
In Sweden it is the measuring accuracy according to SS-EN 16211.
In France, if the measuring device's uncertainty meets the requirement, the uncertainty on the measurement is fixed at 15% for the flowrate, at 10% or 5 Pa for the pressure.
In the USA, there is no target flow rate in the protocol, it describes testing procedures only.

What if an air inlet is missing?

In Belgium, France, Ireland and Sweden, if an air inlet is missing the dwelling/local is considered as not conform.
The respondent from the USA did not specify his answer.

4 ACKNOWLEDGEMENTS

This work was supported by BCCA and INIVE. The views and opinions of the authors do not necessarily reflect those of BCCA or INIVE. The published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall authors, BCCA or INIVE be liable for damages arising from its use. Any responsibility arising from the use of this report lies with the user.

5 REFERENCES

Department of Housing, Planning and Local Government, 2019. Installation and Commissioning of Ventilation Systems for Dwellings - Achieving Compliance with Part F 2019.

Durier, F., Wouters, P., De Strycker, M., Guyot, G., Sherman, M.H., Leprince, V., Urbani, M., 2019. Feasibility Study EPBD Art. 19a - Existing regulations, standards and guidelines on the

inspection of ventilation systems, and other relevant initiatives and projects (No. ENER/C3/2018-447/05). Client: European Commission's Directorate General for Energy.

Jobert, R., Guyot, G., 2013. Detailed analysis of regulatory compliance controls of 1287 dwellings ventilation systems, in: Proceedings of the 34th AIVC - 3rd TightVent - 2nd Cool Roofs' - 1st Venticool Conference. Athens, Greece.

6 ANNEXE 1: LIST OF THE 21 PROTOCOLS FOR THE INSPECTION OF VENTILATION SYSTEMS

Country	Inspection protocol	Type			Mandatory?		
		Legislation regulation	Guidelines	Standards	Yes	No	Comments
Sweden 	Regelsamling för funktionskontroll av ventilationssystem, OVK*	x			x		By law
	VVS Allmän Material och Arbetsbeskrivning, VVS AMA - General material and workmanship specifications on HVAC		x			x	Between 90 and 95% of all building projects in Sweden refer to AMA in the contract documents
Finland 	Finnish Decree 1009/2017 on the indoor climate and ventilation of new buildings	x			x		By law
	Inspection guidelines for ventilation systems by the HVAC Association of Finland SuLVI		x			x	
	Inspection of the cleanliness od ventilation systems - Finnish guidelines LVI 39-10409		x			x	
Poland 	Polish requirements for the inspection of ventilation systems in residential buildings Dz.U. 1994 Nr 89 poz. 414	x			x		By law
Ontario State (Canada) 	Ontario Regulation 67/93 Health care and residential facilities	x			x		By regulation
France 	French standard NF DTU 68.3 - Mechanical ventilation installations			x		x	Specific contract can make it mandatory
	Practical Guide DIAGVENT		x			x	
	PROMEVENT*		x			x	Mandatory for Effinergie label
	Inspection of natural and hybrid ventilation systems		x			x	
	Inspection of newly-installed balanced ventilation systems in residential buildings (in accordance with DTU 68.3)		x			x	

	French protocols for the initial inspection of ventilation systems by the installer		x			x	
	French documents for self-check by installers of the quality of installation of residential ventilation systems		x			x	
USA 	ANSI/RESNET/ICC 380-2016 Testing airflow of mechanical ventilation systems *			x		x	
	ASHRAE Indoor Air Quality Guide		x			x	
Belgium 	Unified Technical Specifications STS-P 73-1 Systems for the basic ventilation in residential applications*	x			x		Used in Flanders where inspection is mandatory
	Practical guidelines for residential building basic ventilation Technical information note – NIT 258		x			x	Can be made mandatory by specific contracts and can be considered as a reference document in the courts
Netherlands 	The Dutch voluntary ventilation inspection (VPK)		x			x	Can be used in certification programs
Germany 	VDI 6022 -1 Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems and units		x			x	
Ireland 	Installation and Commissioning of Ventilation Systems for Dwellings - Achieving Compliance with Part F 2019*	x			x		The guide covers a range of frequently occurring situations but is not exhaustive and alternative means of achieving compliance with the ventilation requirements in the Building Regulations may be possible

* The 5 protocols for which technical details are given in section 3 (data collected with a survey)

FORMATTING INFORMATION

Style of heading 1 is given below.

7 HEADING 1

Style of heading 2 is given below.

7.1 Heading 2

Tables are numbered. The table caption is above the table.

Table 1: Table Caption

Column Title	Column Title	Column Title	Column Title	Column Title
Table content				

Figures are numbered. The figure caption is below the figure.

Figure 1: Figure caption

Equations are numbered:

$$A = B + C \quad (1)$$

$$D + E = F \quad (2)$$

8 CONCLUSIONS

Please refer to the main conclusions of the work.

9 ACKNOWLEDGEMENTS

Please list the individuals that provided help to this work, if any.

10 REFERENCES

In the text, references that are cited in a reference list should mention the author's surname and the year of publication. Example:

Zaslow (Zaslow, 1988) *emphasizes the role of natural resource exploitation in the opening up of Canada's Arctic. Others* (Crowe, 1974) *have described the same period from the point of view of Aboriginal history.*

Crowe, K. (1974). *A History of the Original Peoples of Northern Canada.* Montreal: McGill/Queen's University Press for the Arctic Insitute of North America.

Zaslow, M. (1988). The Northward Expansion of Canada. *The Journal of Canada, 2*(3), 216-222.