Analyses of 1,000 ductwork airtightness measurements in France

In France, a national database from qualified testers' data included in 2017 about 1,000 ductwork airtightness measurements that were performed mainly in new highly efficient buildings. This paper presents first analysis of this database, including ventilation system main characteristics and the most frequent results depending on the type of building. It is based on a paper presented at the 38th AIVC - 6th TightVent & 4th venticool Conference, 2017 "Ventilating healthy low-energy buildings" held on 13-14 September 2017 in Nottingham, UK.

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Duct leakage is known to be detrimental to energy performance and indoor climate (Andersson, 2013) (Carrié, 1999). In order to limit the negative effects of leaky duct systems, French authorities developed an approach to improve ductwork airtightness which builds on the success and lessons learnt from the envelope airtightness approach, including mandatory justification of the airtightness level achieved with third-party testing, unless the default value is used (Charrier, 2017). These ductwork airtightness requirements are expected to boost the market similarly to what happened with the envelope airtightness market as described by Charrier (Charrier, 2015).

In the French EPB regulations, a default value for ductwork leakage class can be used. Based on leakage classes defined in EN standards 12237 and 1507, the default value corresponds to 2.5*class A. Since the current EPB regulation (RT2012), if a better-than-default class is used, it must be justified. Furthermore, the Effinergie+ and BEPOS-Effinergie labels, firmly based on the current regulation, require justifying achieving ductwork leakage Class A as a minimum (Carrié, 2016). **Figure 1** gives an overview of the evolution of the regulatory and voluntary requirements since 2000. Note that both residential and non-residential buildings are concerned. The Effinergie+ and BEPOS labels are meant to experiment requirements for future updates of the regulation, similarly to the past BBC-Effinergie label (tightening RT2005 regulatory levels) which has been very popular and useful to tune the requirements of the RT2012 regulation.

The RT2012 regulation gives two options to justify using a ductwork airtightness class different from the default value as input in the EPB calculation. The class achieved can be justified:

- Either with a ductwork airtightness measurement, performed by a certified tester;
- Or by the application of a certified quality manage-

ment approach (QMA) on ductwork airtightness that allows testing only a sample of buildings. Although a similar QMA option is popular for envelope airtightness (Charrier, 2014), it has never been used in practice for ductwork airtightness and is currently under revision. In both cases, ductwork airtightness tests must be performed by a third-party tester, qualified by the certification body Qualibat.

Presentation of the French national ductwork airtightness measurement scheme and its database

Qualification requirements

In 2012, Effinergie introduced a training scheme for testers within the creation of the Effinergie+ label. Then, the government created a qualification for ductwork airtightness testers. To be qualified, a tester has to:

- Undergo a qualifying State-approved training;
- Pass the training examination (the theoretical part, with a State-approved multiple-choice questionnaire; and the practical part, with a test performed in situ with a certified tester),
- Justify sufficient testing experience.

Once qualified, every tester is subjected to yearly follow-up checks, organized by the certification body. The follow-up checks include an analysis of some reports to verify their compliance with applicable standards and guidelines. Checks are based on the documentation sent every year, but also on site, in particular, in case of complaints or doubts about the quality of their work. Those checks can lead to de-qualification. As of February 2017, 58 testers have been qualified by Qualibat.

Tests have to comply with the European standards EN 12237, EN 1507, EN 13403 and EN 12599, and with the French technical report FD E 51-767. For the Effinergie labels, testers have to additionally comply with the Effinergie measurement protocol, and soon with the recently issued Promevent protocol. Whenever a test is performed, either for a certified QMA or for a systematic test, it must be performed after any works that could impact the final ductwork airtightness. FD E 51-767 specifies the reporting format. In particular, the report indicates if the ductwork airtightness complies with the input class used in the EP calculation. A new version of FD E 51-767 should be published soon. It has been modified to ease the measurement and avoid damage to the ductwork when preparing the section under test.

Development of a ductwork measurements database

Each qualified tester is required to fill in a register with all test results and communicate this register to the certification body every year for verification purposes. This register includes:

- Building general information: owner, location, use, year of the construction, year of the rehabilitation;

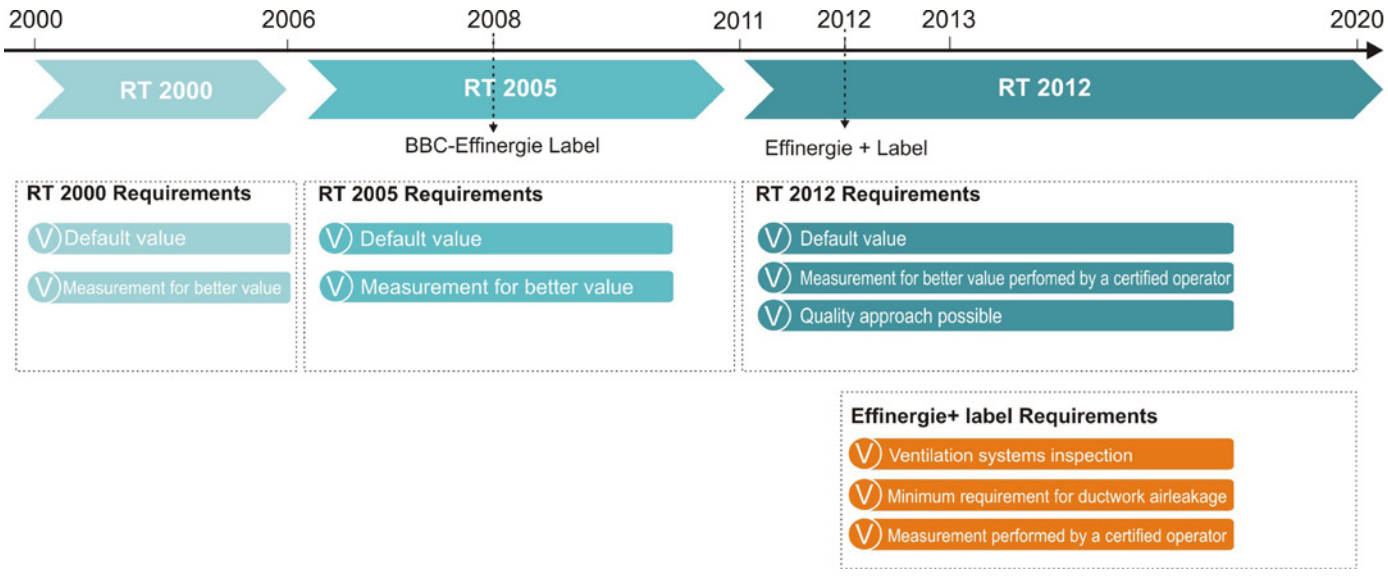

Figure 1. Evolution of French requirements on ductwork airtightness since 2000 for residential and non-residential buildings.

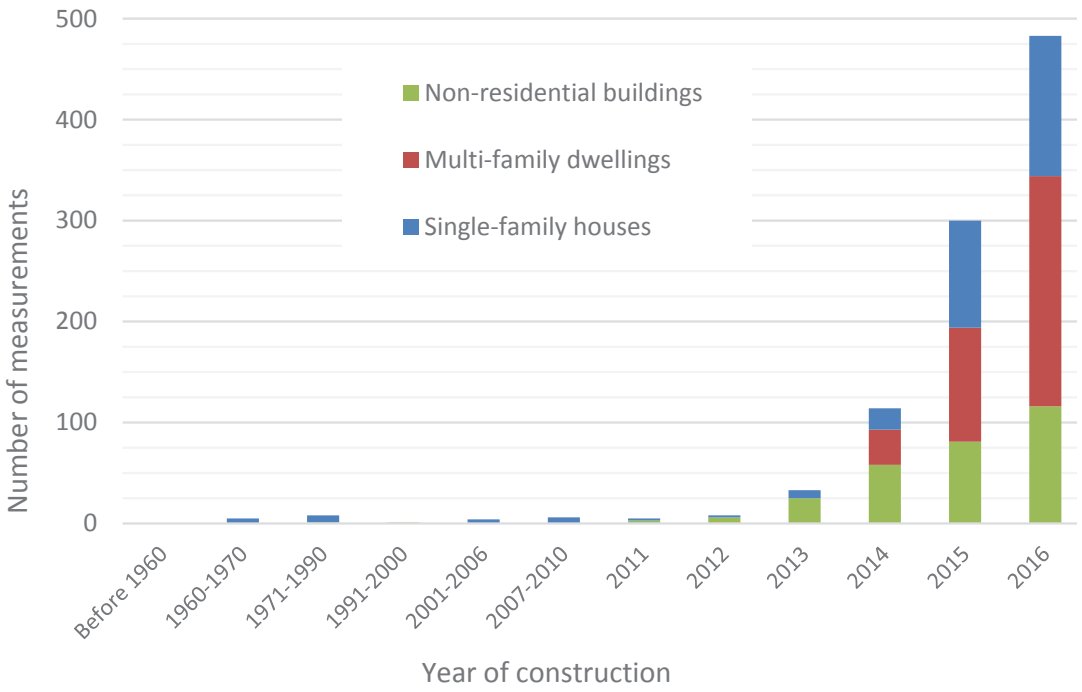

Figure 2. Number of ductworks airtightness measurements depending on the construction year and the use of the building.

- Special requirements: label, certification, ductwork airtightness class target;
- Ventilation system main characteristics: number of stories, type of system, nature, geometry and insulation of ducts, type of terminal devices;
- Measurement protocol: tester's name, date of measurement, measurement device, time of measurement (building state);
- Measurement input data: ductwork surface area, test pressure;
- Measurement results: leakage airflow, leakage factor f, airtightness class.

All registers are consolidated in a common database. Currently, 983 measurements have been recorded in the database. Those measurements were performed by certified testers since the introduction of the training scheme in 2012 (last updating in January 2017). A similar scheme exists since 2007 regarding building airtightness. It has led to a growing database of more than 100,000 tests (Bailly et al., 2016).

Results

Main characteristics of buildings and ventilation systems in the database

Measurements registered in the database were essentially performed in new buildings: 97% of measurements have been performed in buildings built after 2011 (see **Figure 2**). Although earlier ductwork airtightness measurements were only performed in non-residential buildings, we observe that the number of measurements performed in single-family houses and multi-family dwellings significantly increased the last 2 years. They represented 76% of the measurements performed in 2016.

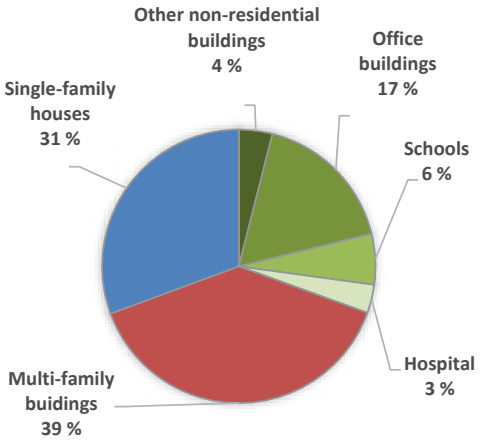

Figure 3. Distribution of buildings' use.

Figure 3 shows that for non-residential buildings, measurements were essentially performed in office buildings, schools, and hospitals.

In new French buildings, either balanced ventilation systems or single-exhaust ventilation systems are implemented. **Figure 4** shows that residential buildings, both multi-family dwellings, and single-family houses, are mainly equipped with single-exhaust ventilation systems, and non-residential buildings are equipped with balanced ventilation systems.

Those figures cannot be generalized to all new French buildings. In fact, low-energy certified buildings represent 44% of the measurements recorded in the database but only 10% of the new building stock in France.

Three different types of ducts are used: rigid ducts, semi-rigid ducts, and flexible ducts. **Table 1** presents the distribution of the type of ductwork depending on the building's use and the type of ventilation system. Balanced ventilation systems are mainly connected to rigid ducts, especially in non-residential buildings. For single-exhaust ventilation system, it depends on the type of building. Rigid ducts are widely used both in non-residential buildings and multi-family buildings. On the contrary, flexible ducts are the main type of ductwork implemented in single-family houses equipped with single-exhaust ventilation systems. This practice is consistent with the type of ducts generally implemented in all buildings in France, as it corresponds to the French standards and professional recommendations.

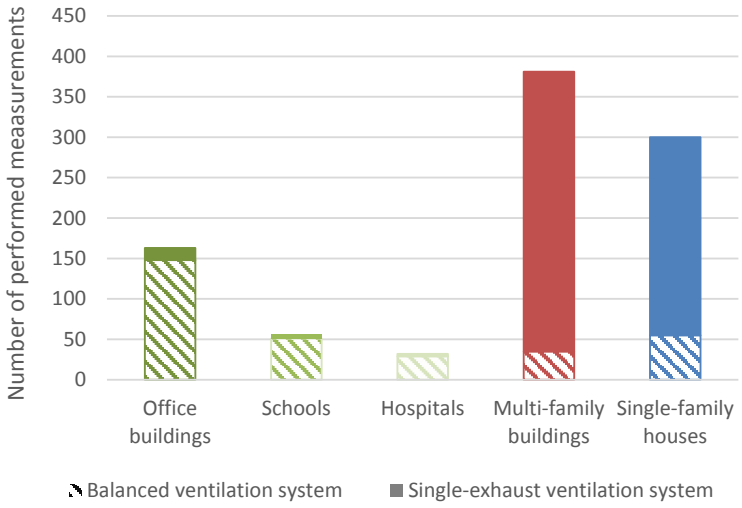

Figure 4. Type of ventilation system depending on buildings' use.

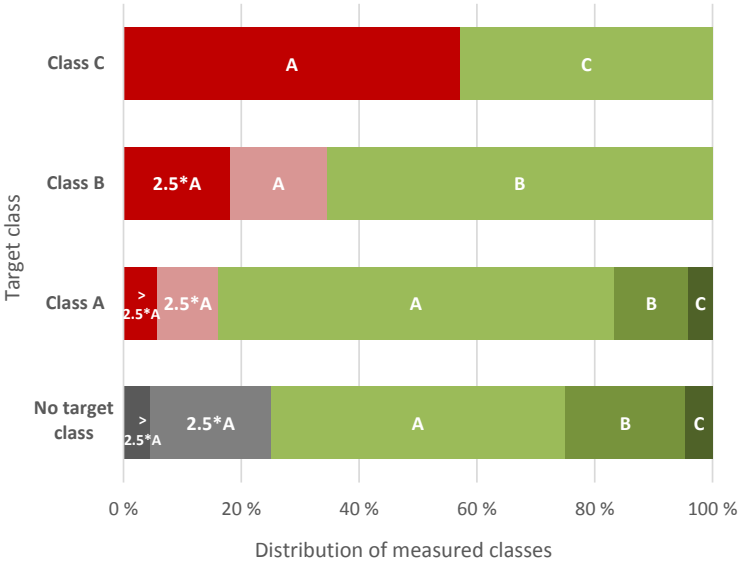

Figure 5. Specific ductwork airtightness measured class depending on target class.

Table 1. Type of implemented ducts depending on building's use and type of ventilation system.

	Balanced ventilation system			Single-exhaust ventilation system		
	Rigid ducts	Semi-rigid ducts	Flexible ducts	Rigid ducts	Semi-rigid ducts	Flexible ducts
Office buildings	**85%**	0%	5%	11%	0%	0%
Schools	**79%**	0%	11%	11%	0%	0%
Hospitals	**89%**	0%	0%	7%	0%	4%
Multi-family buildings	4%	2%	3%	**78%**	1%	12%
Single-family houses	7%	5%	6%	4%	3%	**75%**

Measured ductwork airtightness classes

Ductwork airtightness measurements are performed in order to justify either the respect of an certification requirement, the respect of an EP-calculation declaration, or without specific requirement. The information regarding target classes is available for about half of the measurements (521), amongst which 23 measurements target class C, 91 target class B, 305 target class A and 153 are declared as "no target class". As shown in **Figure 5**, the distribution of the specific ductwork airtightness measured class depends on the chosen target class:

- when the most airtight class (class C) was targeted, less than half of the measured ductworks meets the target (almost only hospitals). For the others, the quality of the ductwork is significantly poorer as they only achieve class A;
- when class B or class A was targeted, most ductworks meet this target class or better. However, 16% (target class A) and 35% (target class B) of the measured ductworks achieve worse classes;
- when the measurement was performed with "no target class", the results are quite good as 75% of the measured ductwork reach class A or better. Even thought there was no target class, mandating a measurement suggests a special awareness regarding ductwork airtightness for those buildings, i.e. presumably better results than the average. Again, it should be noted that these results only apply to the buildings of the database and cannot be generalized to all new buildings in France.

Figure 6 presents the results of ductwork airtightness measured class in residential buildings. For both single-family houses and multi-family buildings, most measured ductworks met leakage class A (respectively 64% and 54%). In multi-family buildings, 23% of measured ductworks achieved a better class (mainly B), whereas ductworks of higher classes are only 7% in single-family houses. The wide use of flexible ducts in single-family houses could explain these results (see **Table 1**).

Figure 7 presents the results of ductwork airtightness measured class in non-residential buildings. Ductworks in these buildings are overall tighter than in the residential sector: 48% of them meet class B. Even if our sample is too small to make statistics, we observe that the class C is more frequently achieved in hospitals where rigid ducts are widely used.

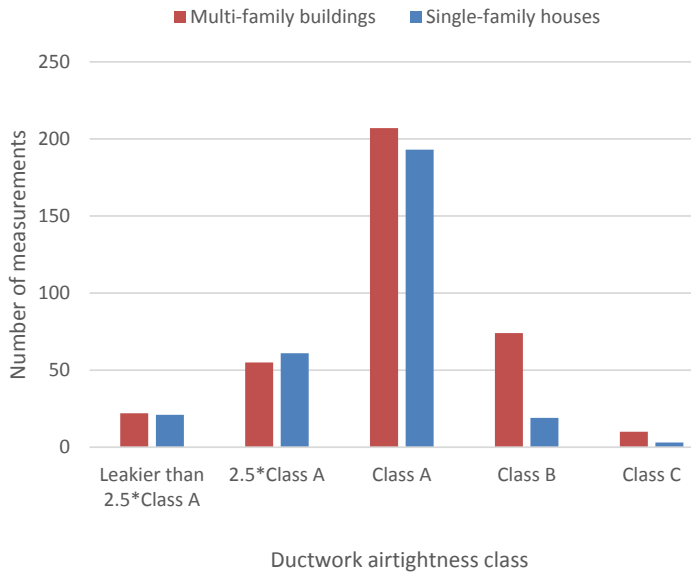

Figure 6. Specific ductwork airtightness measured class in residential buildings.

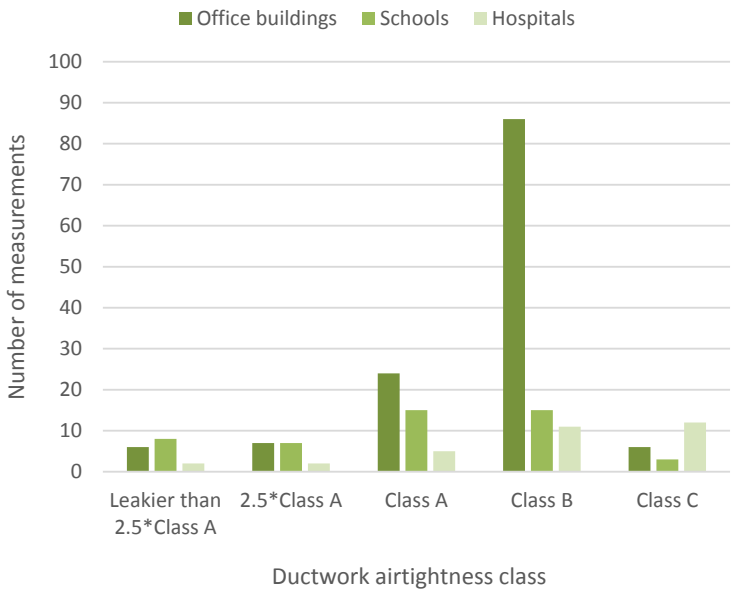

Figure 7. Specific ductwork airtightness measured class in non-residential buildings.

Conclusions

The French Ministry in charge of construction created a qualification scheme for ductwork airtightness testers since 2012. Each qualified tester is thereby required to feed a database with building general information, targeted certification and/or class, ventilation system's main characteristics, data on the measurement protocol, measurement input data and measurement output results. So far 983 measurements have been logged in the database. The number of ductwork airtightness measurements that are performed by qualified testers is growing each year, with almost 500 measurements in 2016.

All measurements considered in the database were performed:

- on new residential building: both multi-family buildings and single-family houses, mainly equipped with single-exhaust mechanical ventilation systems;
- on new non-residential buildings: mostly office buildings, schools, and hospitals, mainly equipped with balanced mechanical ventilation systems.

In residential buildings, most measured ductworks met leakage class A. In non-residential buildings, ductworks are overall tighter: almost half of them met class B. Nevertheless, when a target class was defined, it was not widely achieved, especially for the tightest class, class C.

All measurements in the database were performed according to specific and not common demands. Thus, all results presented in this paper only apply to the buildings of the database and cannot be generalized to all new buildings in France. ■

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