TESTING A METHOD FOR THE EVALUATION OF THE AIRTIGHTNESS OF VENTILATION SYSTEMS IN EXISTING BUILDINGS

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ABSTRACT

The airtightness of ventilation ductwork is an important element of the global performance of ventilation systems. Nevertheless, it is too often neglected in practice.

Today, the new French Thermal Regulation (RT2000) encourages taking it into account as the energy losses calculation includes an additional part which is directly related to the additional air flow through ductwork leakages.

If we want to improve the results and the practice, we have to take into consideration the whole ventilation installation : the ducts and accessories, of course, but also the connections between ducts and air terminal devices, the connections between ducts and fan units, the characteristics of these fans, CTA, etc. We also have to take into account the reality of the building site.

This paper shows how to implement a methodology for measuring, on site, the global airtightness of ventilation installations. It is based on real applications on commercial and residential buildings, in France. It shows the feasibility of the method and, notably, the difficulties which were encountered for the investigations in multi-family buildings.

Measurements results are given and compared to the standard classes. They show the poor quality of airtightness on the most of installations which were tested. These results are in agreement with previous studies.

In parallel, this work enables to identify some of the causes of the low airtightness of ventilation systems.

KEYWORDS

Ventilation, Ductwork, Airtightness, Measurements, Leakage.

METHODOLOGY

The following methodology is applied, for each operation (after discussion with the owner or building administrator, to explain the goals and to get the permissions):

- Check the available documents which describe the ventilation system: drawings, requirements, components characteristics, …; in order to recognize the installation and select, if necessary – or to simplify -, a part of the ductwork for the measurements;

- Close up the exhaust air terminal devices (exhaust ATD) (exhaust system is the most used in France) : either with adapted cap where possible, or with small balloons equipped with a small rubber tubing which can easily be blocked (this method was specially tested in this study);

- Measure the residual air flows on certain parts of the network, or the global air flow at the fan unit; measure the pressures in different points. Sometimes, the air leakage is calculated by the comparison between the global ventilation air flow at the fan box and the addition of the individual air flows at every exhaust ATD, in normal use. The measurement devices are, mainly : balometer (ex. measuring the air flow at the fan unit exhaust – for small fan boxes) ; hot wire anemometer ; manometer, …;

- Look for the visible leakages if there are (some open connections were found) ; this is made by a detailed inspection of the network, as much as possible, everywhere it is possible; sometimes smoke test can be used;

- Make a precise description of the ventilation ductwork: lengths, diameters, reductions, etc. Available drawings are used ; but if there are not, then a detailed inspection has to be made ; the aim is to get a description of the ductwork as precise as possible;

- Analyse the results: tables, graphs, elementary calculations. Establishing a database on the ventilation ductwork components and their « areas » (for the evaluation of the total ductwork area which can be used in some leakages ratios).

RESULTS

Example of detailed results is shown on a Middle School, and then a summary of the results on four buildings (Middle School, Nursery School, Multi-Family A & B) is presented: tables, ratios, graphs.

Example of detailed results: Middle School building

Picture 1: Middle School (year of construction: 1998)

Ventilation system

Simple exhaust ventilation system for classrooms.
The fan unit is on the roof; nominal air flow rate is around 2500 m3/h; it serves seven classrooms and two technical rooms (archives).

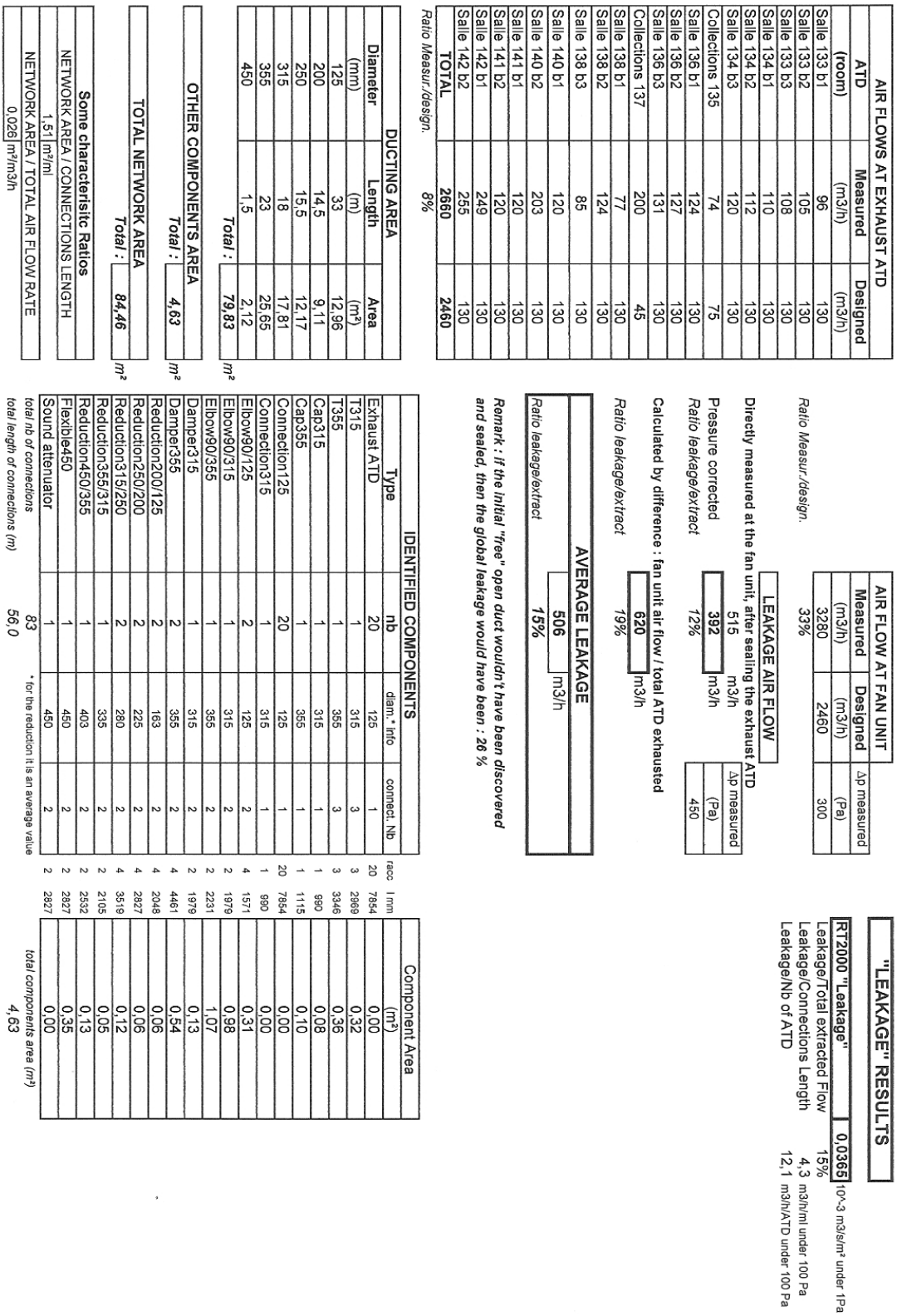
List of observations (see the following pictures)

- The inspection took place during holidays (spring) ; because out of this period it would have been difficult to enter the different rooms;
- Detailed drawings of ventilation ductworks were available, on site;
- For sealing the exhaust ATD, small balloons were used, without any difficulty;
- The links between flexible ducts and rigid ones (on the terminal parts of the ductwork) appeared not to be very airtight ; one reason is the lack of specific connection component;
- One open connection duct was found inside a coffered ceiling (125 mm diameter); it was then sealed with a special cap;
- Some connections between exhaust ATD were visibly not airtight at all;
  (these terminal defaults are not taken into account in the global network leakage evaluation, because the small balloons were placed downstream)
- The links between the main ventilation duct and the secondary ducts were airtight, due to the use of tape and mastic (no leakage could be visualised with the smoke test) ; also along the main duct, the connections between duct components (deviations, reductions) were visibly airtight;
- On one part of the network (one classroom, two exhaust ATD) the extracted air flow was really too high and a lot of noise was emitted inside the classroom; it seemed that a terminal regulation component was lacking (for the moment, the situation has been improved by closing an air damper on the roof part of the network; then the air flow and the noise were significantly reduced in the classroom).

		
Picture 2: Removing an exhaust air terminal device (exhaust ATD)	Picture 3: Connection between a flexible duct and a rigid duct	Picture 4: Terminal part for the exhaust ATD connection
		
Picture 5: Preparing the small balloons to close up the exhaust ATD	Picture 6: ”open duct”, which was discovered inside the coffered ceiling	Picture 7: Smoke test for leakages visualization; here, the connection is well mounted and airtight

Detailed results on air flow measurements, ductwork area, and leakages

The ductwork leakage is expressed in m^3/h and also, according to the French regulation, in $10^{-3}m^3/s/m^2$ under 1 Pa. Other ratios are calculated, for example “leakage/total extracted air flow rate”.



MIDDLE SCHOOL

NETWORK n°3 | CLASSROOMS (B1) | (total floor area arround : 516m²)

AIR FLOWS AT EXHAUST ATD

ATD (room)	Measured (m3/h)	Designed (m3/h)
Salle 133 b1	96	130
Salle 133 b2	105	130
Salle 133 b3	108	130
Salle 134 b1	110	130
Salle 134 b2	112	130
Salle 134 b3	120	130
Collections 135	74	75
Salle 136 b1	124	130
Salle 136 b2	127	130
Salle 136 b3	131	130
Collections 137	200	45
Salle 138 b1	77	130
Salle 138 b2	124	130
Salle 138 b3	85	130
Salle 140 b1	120	130
Salle 140 b2	203	130
Salle 141 b1	120	130
Salle 141 b2	120	130
Salle 142 b1	249	130
Salle 142 b2	255	130
TOTAL	**2660**	**2460**
Ratio Measur./design.	*8%*	

AIR FLOW AT FAN UNIT

Measured (m3/h)	Designed (m3/h)	Δp measured (Pa)
3280	2460	300
33%		

Ratio Measur./design.

LEAKAGE AIR FLOW

Directly measured at the fan unit, after sealing the exhaust ATD

515 m3/h | Δp measured (Pa): 450

Pressure corrected — 392 m3/h

Ratio leakage/extract — *12%*

Calculated by difference : fan unit air flow / total ATD exhausted

620 m3/h

Ratio leakage/extract — *19%*

AVERAGE LEAKAGE

Ratio leakage/extract — 506 m3/h — *15%*

Remark : if the initial "free" open duct wouldn't have been discovered and sealed, then the global leakage would have been : 26 %

"LEAKAGE" RESULTS

RT2000 "Leakage"	0,0365	10^-3 m3/s/m² under 1Pa
Leakage/Total extracted Flow	15%	
Leakage/Connections Length	4,3	m3/h/ml under 100 Pa
Leakage/Nb of ATD	12,1	m3/h/ATD under 100 Pa

DUCTING AREA

Diameter (mm)	Length (m)	Area (m²)
125	33	12,96
200	14,5	9,11
250	15,5	12,17
315	18	17,81
355	23	25,65
450	1,5	2,12
	Total :	*79,83* m²

OTHER COMPONENTS AREA

Total : *4,63* m²

TOTAL NETWORK AREA

Total : *84,46* m²

Some characteristic Ratios

NETWORK AREA / CONNECTIONS LENGTH — 1,51 m²/ml

NETWORK AREA / TOTAL AIR FLOW RATE — 0,026 m²/m3/h

IDENTIFIED COMPONENTS

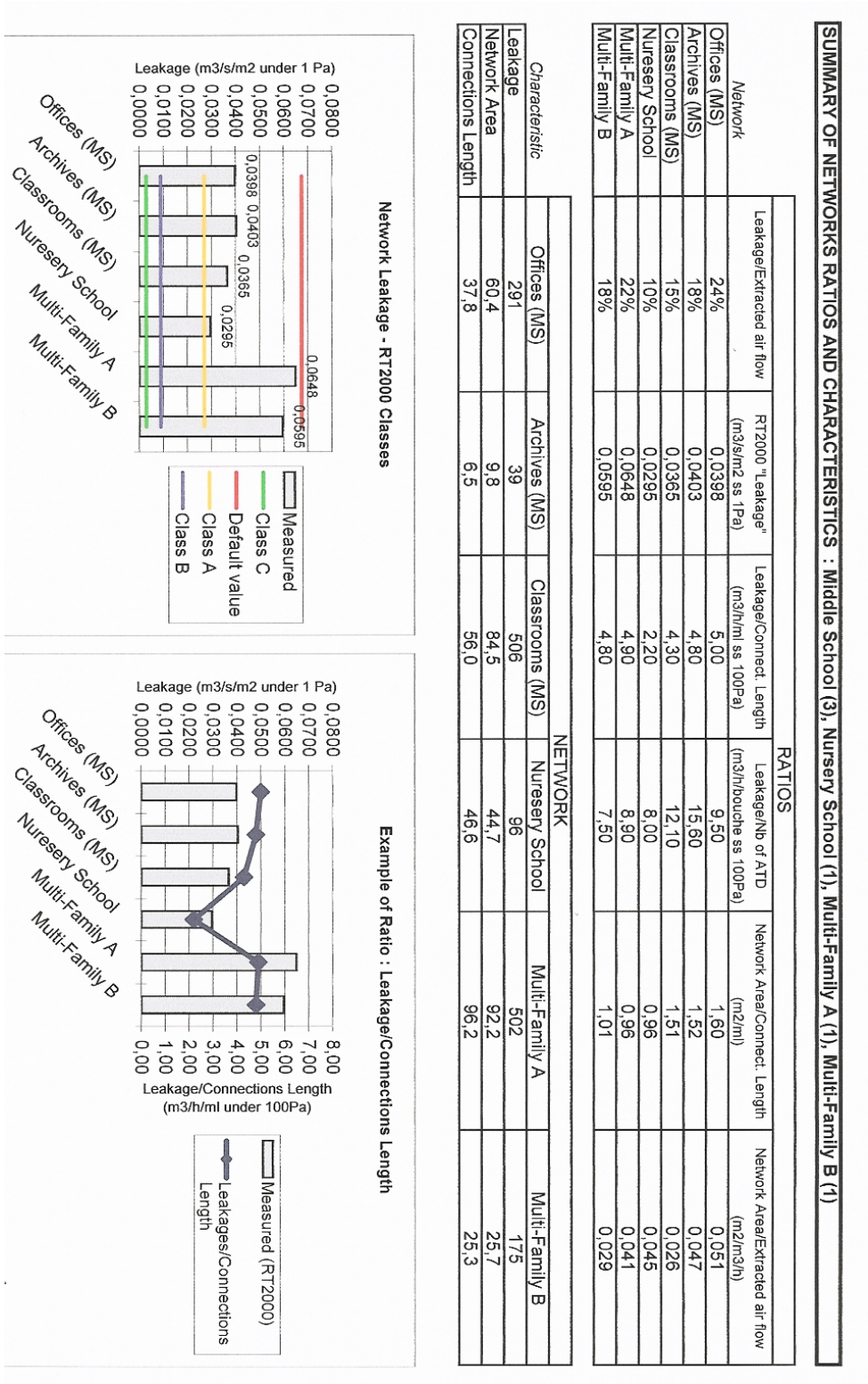
Type	nb	diam. * info	connect. Nb	recc	l mm	Component Area (m²)
Exhaust ATD	20	125	1	20	7854	0,00
T315	1	315	3	3	2969	0,32
T355	1	355	3	3	3346	0,36
Cap315	1	315	1	1	990	0,08
Cap355	1	355	1	1	1115	0,10
Connection125	20	125	1	20	7854	0,00
Connection315	1	315	1	1	990	0,00
Elbow90/125	2	125	2	4	1571	0,31
Elbow90/315	1	315	2	2	1979	0,98
Elbow90/355	1	355	2	2	2231	1,07
Damper315	1	315	2	2	1979	0,13
Damper355	2	355	2	4	4461	0,54
Reduction200/125	2	163	2	4	2048	0,06
Reduction250/200	2	225	2	4	2827	0,06
Reduction315/250	2	280	2	4	3519	0,12
Reduction355/315	1	335	2	2	2105	0,05
Reduction450/355	1	403	2	2	2532	0,13
Flexible450	1	450	2	2	2827	0,35
Sound attenuator	1	450	2	2	2827	0,00
total nb of connections	*83*					*total components area (m²)* *4,63*
total length of connections (m)	*56,0*					

* for the reduction it is an average value

Figure 1: Detailed results for the network n°3, in the Middle School

Summary of the results on four buildings and six ventilation networks

Different ratios are presented, and also, on the graphs, the situation of the different systems by comparison with the leakages classes according to the French regulation.



SUMMARY OF NETWORKS RATIOS AND CHARACTERISTICS : Middle School (3), Nursery School (1), Multi-Family A (1), Multi-Family B (1)

Network	RATIOS				
	Leakage/Extracted air flow	RT2000 "Leakage" (m3/s/m2 ss 1Pa)	Leakage/Connect. Length (m3/h/ml ss 100Pa)	Leakage/Nb of ATD (m3/h/bouche ss 100Pa)	Network Area/Connect. Length (m2/ml)	Network Area/Extracted air flow (m2/m3/h)
Offices (MS)	24%	0,0398	5,00	9,50	1,60	0,051
Archives (MS)	18%	0,0403	4,80	15,60	1,52	0,047
Classrooms (MS)	15%	0,0365	4,30	12,10	1,51	0,026
Nuresery School	10%	0,0295	2,20	8,00	0,96	0,045
Multi-Family A	22%	0,0648	4,90	8,90	0,96	0,041
Multi-Family B	18%	0,0595	4,80	7,50	1,01	0,029

Characteristic	NETWORK				
	Offices (MS)	Archives (MS)	Classrooms (MS)	Nuresery School	Multi-Family A	Multi-Family B
Leakage	291	39	506	96	502	175
Network Area	60,4	9,8	84,5	44,7	92,2	25,7
Connections Length	37,8	6,5	56,0	46,6	96,2	25,3

Figure 2: Tables and graphs, showing the leakages and the characteristics of the 6 ventilation networks which were studied: Middle School (3), Nursery School (1), Two Multi-family Buildings (2)

FIRST CONCLUSIONS AND PERSPECTIVES

This first study (four buildings, six ventilation networks) contributed to improve our knowledge and practical experience on the ventilation network airtightness.

None of the tested ventilation ductworks fulfilled the Class A requirements for leakages, according to the new French regulation RT2000. Leakages values were comprised between Class A and the default value (the default value is 2,5 higher than the Class A). For the two multi-family buildings the airtightness of the ventilation system was comparable, and close to the default value, according to RT2000; both cases were significantly worth compared to the others.

It seems that the poor quality of the airtightness of the ventilation system is often due to the terminal parts of the ductwork; further investigations on another multi-family building revealed strong defaults (see picture n°8, below) which led to higher leakages values. Bad airtightness is also due, in some cases, to major errors like an open duct without any ATD (see picture n°6, above); a visual inspection before coffering the ceiling would allow to avoid such a mistake.

Picture 8: (Multi-Family Building) Connecting duct (flexible) with a strong leakage (the ATD has been removed, it was directly – and bad – mounted on the connecting duct)

To analyse the results, a correlation like « leakage/connections length » seems to be interesting to study; but the defaults are not only localized at the connections.

A future commitment on airtight ventilation systems will suppose, in addition with efforts on conception, installation and maintenance, also to schedule and organise the commissioning (in residential buildings, it seems to be difficult because of the very short period between the end of the construction act and the arrival of the owners).

Today, ALDES is developing a new fan unit (with an integrated air flow measurement device) which will allow to measure the ductwork leakage, the apartments leakages, and also to check the nominal ventilation air flow rate.

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