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AIRTIGHTNESS MEASUREMENTS IN THREE DWELLINGS IN ROME

G Fasano[1], G Girogiantoni[2] and G Guili[3]

1-2-3 ENEA The Italian Committee for the New Technologies, Energy and the Environment
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Synopsis

Airtightness measurements are not yet common in the Italian dwelling stock.In the framework of the MICA-ENEA contract, three dwellings were chosen to study the energy performance on the influence of natural agents. The majority of the dwellings in Italy still nowdays rely on natural ventilation and records of the fluidynamic and energy performance are not contractual documents among the parties involved. Since building airtightness is an important parameter to be investigated in case of natural ventilation, this study takes into consideration three typical examples of the Italian dwelling stock located in three different districts of the urban area and cover the range of constructions starting from the beginning of the century up to eighties before the actual heavy decrement of the new constructions .

The three dwellings are located in Rome and they have the following caracteristics:

1. dwelling located downtown in a 1915 building (Dw-1),
2. dwelling located in the south-east region of the city, in the residential areas built in the 70's (Dw-2),
3. dwelling located in the north region of the city, in the residential areas built in the 80's (Dw-3),

The instrumentation to be used includes a blower door, data logger and computer with the dedicated software to perform depressurization tests up to 50 Pa, to obtain ACH and ELA and in general all the parameters which might be of interest to foresee the behaviour of the dwellings during natural ventilation under the influence of the urban environmental conditions.

List of symbols

ACH@50 Pa = Air changes per hour at a pressure difference ext.-int. of 50 Pa
EqLA = Equivalent leakage area, cm^2.
ELA = Effective leakage area, cm^2
Pa = Pressure, N/m^2

Methods

A ***Minneapolis Blower Door mod-3*** was installed in two cases in the external perimeter of the dwelling, while in the newest one the door was installed in the entrance door.

The blower door consists of four components :

- Blower Door Fan
- Door Frame (aluminium model)
- DAB (Data Acquisition Box) 8 channels data logger plus portable computer in which APT (Automated Performance Testing System) ver 1.0 software was installed.
- Accessory case.

Blower Door Fan

The Blower Door Fan consists of a precision molded fan housing with a 550 W AC motor capable of moving up to 10 900 m^3/h of air. Air flow through the fan is determined by measuring the slight vacuum created by the air flowing over the fan inlet when the fan is operating. It is used to blow air into or out of a house. When air is blown out of the house, it causes a slight negative pressure or vacuum in the house relative to outside. This negative pressure induces outside air to enter the house (infiltration) through cracks or holes found in

any exterior house surface.The Blower door fan meets the flow calibration specifications of both CGSB Standard 149.10-M86 and ASTM Standard E779-87. To accurately measure fan flows less than 4 100 m^3/h of air, calibrated low flow rings are provided and are attached to the fan inlet. The standard Minneapolis Blower Door system comes with 2 low-flow rings capable of measuring as low as 510 m^3/h.
The blower door can be also used to pressurize the house by blowing air into the house and creating a slight positive house pressure relative to outside (exfiltration).

Door Frame
The door frame (and nylon panel) is used to seal the fan into an exterior doorway. It is adjustable to fit any size opening. Final adjustment and sealing are achieved by means of cam levers on the side of the assembler.

DAB (Data Acquisition Box)
The DAB contains 8 pressure channels, along with 8 analog voltage input channels.
Each pressure channel is comprised of a calibrated differential pressure tranducer connected to a pair of 1/8 " OD taps. The pressure channels have a swichable resolution of 0.1 to 0.5 Pascals, with a corresponding range of approximately +/- 400 or +/- 1 000 Pa. Each pressure channel has built-in auto zero capability.
When operating in the automated airtightness testing mode, channel P1 is used to measure the pressure in the building, while channel P2 is used to measure flow through the airtightness testing fan.

Since the confidence with depressurization tests was greater than pressurization or cruise tests, it was decided to start with these first and then the others in a further stage.
Sunny days having negligible wind velocities were chosen, to minimize pressure fluctuations and readings uncertainties, opening for hoods and fireplaces ducts were sealed.
Multi point depressurization tests were undertaken, as shown in the results section.[1]

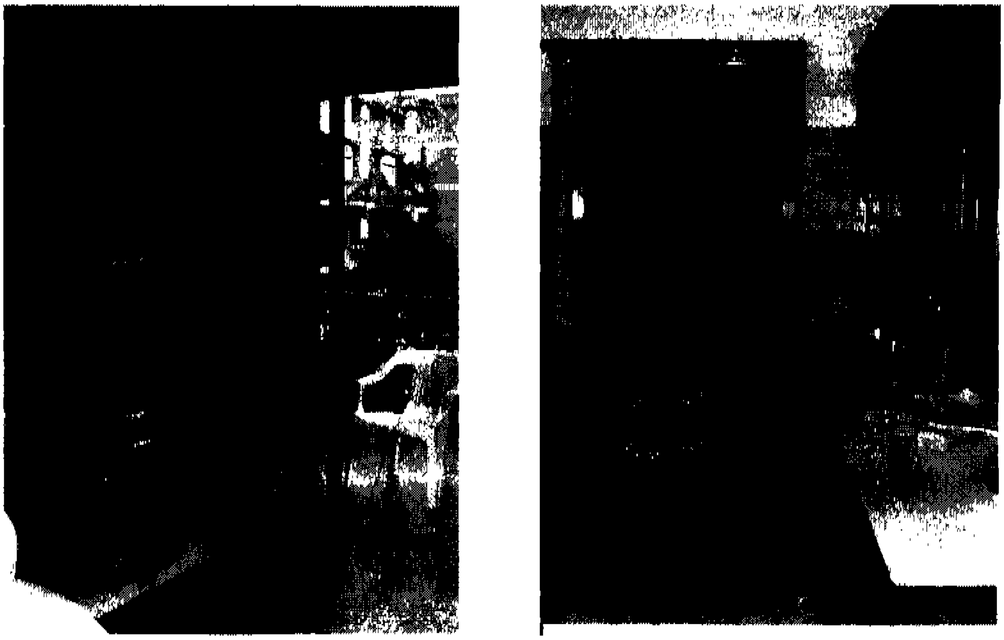


Photo 1- 2 Arrangement of the blower door in Dw-2

Results

Tab.1 Test results

	Dw.Vol. (m^3)	EqLA @ 10 Pa (cm^2)	LBL @ 4 Pa (cm^2)	ACH @ 50 Pa
Dw-1	341	806	458	5.4
Dw-2	322	1665	942	11.9
Dw-3	246	723	406	6.9

Equivalent Leakage Area (**EqLA**), is defined by Canadian Researchers at the Canadian National Research Council as the area of a sharp edged orifice (a sharp round hole cut in a thin plate) that would leak the same amount of air as the building does at a pressure diff. of 10 Pa.

Effective Leakage Area (**ELA**) was developed by Lawrence Berkeley Laboratory (LBL) and is used in their infiltration model. The effective leakage area is defined as the area of a special nozzle-shaped hole (similar to the inlet of the blower door fan) that would leak the same amount of air as the building does at a pressure of 4 Pa.[2] [3]

Once each airtightness test sequence was completed, a "best fit" line (called the Building Leakage Curve) was drawn authomatically through the collected blower door data.

The Building Leakage Curve can be used to estimate the leakage rate of the building at any pressure.

The Building Leakage Curve is defined by the variables Coefficient (C) and Exponent (n) in the following equation :

$$Q = C * P^n$$

where :

Q is airflow into the building (m^3/s).

C is the coefficient.

P is the pressure difference between the inside and outside of the building.

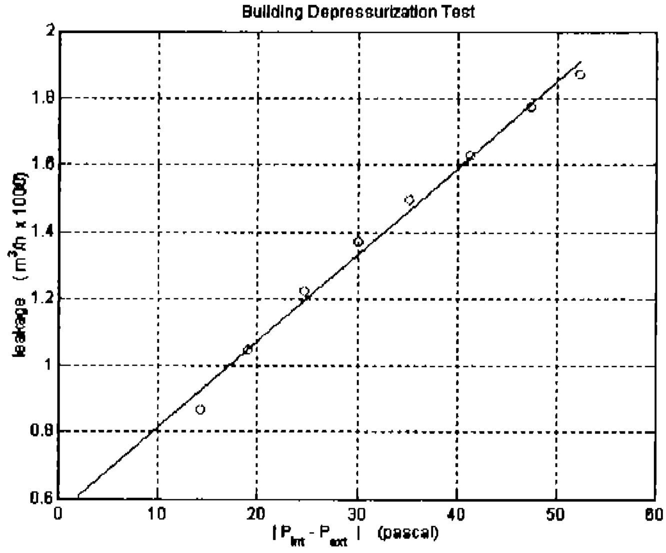
n is the exponent.

We had the following figures :

Tab.2 Building leakage curve

	Flow Coeff. (C)	Exponent (n)	Correlat. Coeff.
Dw-1	111.9	0.579	0.99954
Dw-2	229.6	0.583	0.96919
Dw-3	96.6	0.597	0.99993

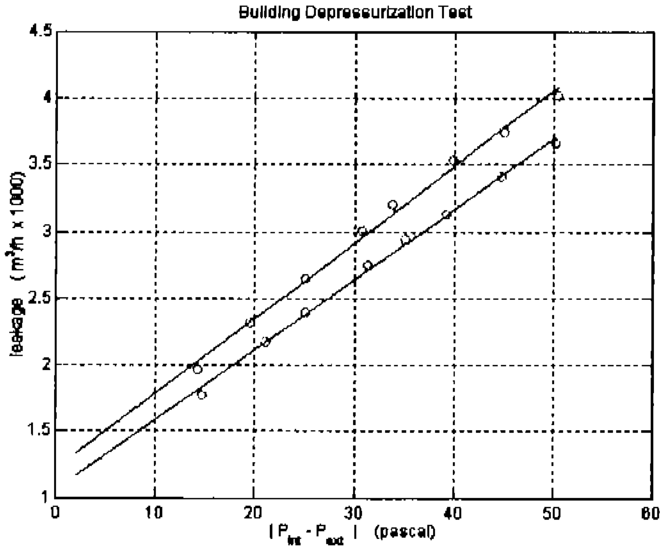
DW–1



Date: 22-APR-1998
Address: Porta Pia
City: Rome - ITALY
Volume: 341.0 m^3
Floor: 111.9 m^2
Surface: 57.4 m^2

	ΔP (Pascal)	FLOW (m3/h)	FLOW (l/sec)
1	52	1871	520
2	47	1773	492
3	41	1631	453
4	35	1501	417
5	30	1370	381
6	25	1225	340
7	19	1047	291
8	14	867	241

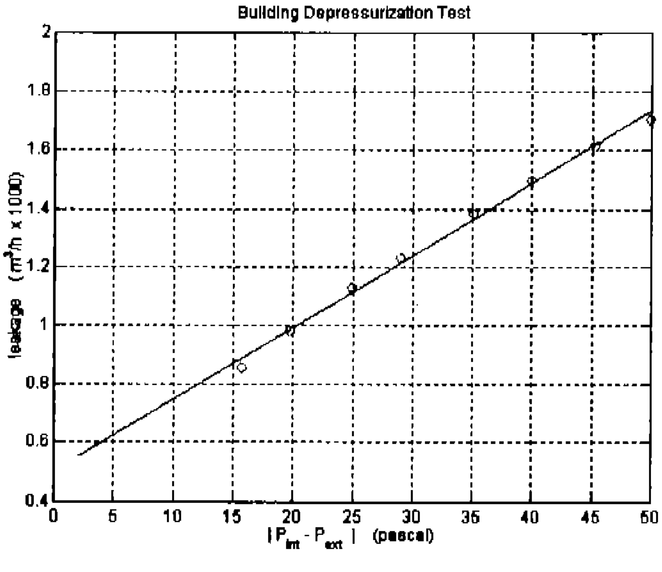
DW–2



Date: 23-APR-1998
Address: Via Rocciatori 21
City: Rome - ITALY
Volume: 322.2 m^3
Floor: 107.4 m^2
Surface: 106.0 m^2

	ΔP (Pascal)	FLOW (m3/h)	FLOW (l/sec)
1	50	4014	1115
2	45	3738	1038
3	40	3531	981
4	34	3206	890
5	31	3007	835
6	25	2656	738
7	20	2310	642
8	14	1963	545
1'	50	3655	1015
2'	45	3407	947
3'	39	3139	872
4'	35	2948	819
5'	31	2758	766
6'	25	2399	666
7'	21	2171	603
8'	15	1771	492

DW–3



Date: 22 – APR - 98
Address: Serpentara - Lotto 12
City: Rome - ITALY
Volume: 245.9 m^3
Floor: 90.8 m^2
Surface: 101.7 m^2

	ΔP (Pascal)	FLOW (m3/h)	F LOW (l/sec)
1	50	1703	473
2	45	1617	449
3	40	1500	417
4	35	1387	385
5	29	1236	343
6	25	1132	315
7	20	982	273
8	16	855	238

Dwellings 1 and 3 are in the European continental average and range (3-10 ACH @ 50 Pa), while the 2nd is too leaky [4].
The equivalent leakage areas which the blower door software outputs, roughly correspond to the combined area of all the house's leaks. These data could be used in the codes to simulate different situations and conditions.
We have to consider that these results are not limited to the groups of the experts dealing with the matter. They have to be used and easily interpretated by the weatherization firms and by those field technicians who have no confidence with the theory.
We report many attempts and simple rules of the thumb to convert the blower door measurements into an average infiltration rate, to simplify the estimations of permeability, energy consumption, since the rate of infiltration is constantly varying while a single pressure test is available.
Experiments carried out in Sw and in Usa gave the result that assuming

$$\textit{average infiltration rate } ACH = \frac{ACH_{50}}{20}$$

the value was surprisingly reasonable. In this formula ACH_{50} denotes the hourly change rate at a pressure difference of 50 Pa between inside and outside.
Further to this, on the basis of the use of climatic data for North America a climate factor to reflect the influence of outside temperature (affects the stack effect) and windiness was developed [5]. Since this factor reflects both temperature and seasonal windiness, a cold, calm location might have the same climate factor as a warm, windy location.

$$\textit{Correlation factor, } N = C * H * S * L,$$

where,
C = climate factor, a function of annual temperatures and wind (ranges from 14 to 26 for North America).

H = height correction factor

Tab.3

N° of stories	1	1.5	2	3
Corr.factor H	1.0	0.9	0.8	0.7

S = wind shielding correction factor

Tab.4

Extent of shield.	Well Shield.	Normal	Exposed
Corr.factor S	1.2	1.0	0.9

L = leakiness correction factor

Tab.5

Type of holes	Small cracks (tight)	Normal	Large holes (loose)
Corr.factor L	1.4	1.0	0.9

An estimate of the average annual infiltration rate is then given by :

$$\textit{average air changes per hour } ACH = \frac{ACH_{50}}{N}$$

This formula provides a more flexible value according to the different cases to be assessed. We have to point out that the field measurements might not be so abundant as required. Furthermore, multiple simulations can enlarge the investigation cases, different climatic conditions, different occupancy can be studied and evaluated.

During these last years our division achieved some capabilities in the use and diffusion of models to predict the trend of the concentrations of the main indoor pollutants in dwellings, offices and hospitals.

To calculate air flows and contaminant dispersal in multizone buildings CONTAM 96 by NIST (National Institute of Standard and Technology) was used[6].This code uses the multizone network approach to airflow analysis.The building is treated as a collection of zones connected by airflow paths.These zones may represent groups of rooms,individual rooms,or even portion of rooms,as well as shafts and portion of the building air handling system.Within each zone the temperature and contaminant concentration is considered to be uniform.The airflow paths include doorways, small cracks in the building envelope, and a simple model of the air handling system (AHU).

Procedures and local standards have been developed in North America and North Europe to find out where is the minimum tightness to be achieved [7].

Larger amounts of infiltration are tolerated in milder climates ;if weatherization works have to be performed is not completely assured from field measures, other factors must be accounted such climate, exposition and the operation of furnaces etc.

In the blower door handbook quick formulas easily give the economical result of weatherization works.

Conclusions

- The blower door resulted in a flexible and adjustable tool, easy to transport from a dwelling to another.
- Tests are brief, interventions and adaptations on the apparatus are minimal, the available software reduces manual calculations and therefore the tests might be undertaken by technicians having normal training.
- Tenants generally wellcome actions which may result in an immediate benefit for their dwelling, since they realize the possible savings in the expences for climatization.

- The empirical indexes are easy and impressive for the definition of inflitrations and exfiltrations. Studies to assess their full correspondence in our mild climates should be undertaken.
- There is not a defined minimum value below which weatherization and sealing should be stopped. Knoweledge of the local climate is necessary.
- Tenant of Dw-2 was surprised to find his apartment so leaky. He realized why in his opinion gas bills were high with respect to similar constructions.
- Tenant of Dw-2 immediately made a remedial work on the frame of the door of his kitchen ; this resulted in an improving of airtightness when the test was repeated (cfr. graph of Dw-2 which is given in two trends).
- Even if windows and doors are shop tested [8] and show in the modern frames values about 7 $m^3/h/m^2$ @ 100 Pa, site erection may be poor and result in high permeability.
- Confidence in computer simulations for indoor air quality will be greatly increased entering the real leakage data, since until now we had to rely on estimated values only.

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