UPDATE OF THE SPANISH REGULATION REGARDING VENTILATION AND INFILTRATION: ANALYSIS, COMPARISONS AND REPERCUSSIONS

Salmerón Lissén José Manuel[1*], Sánchez de la Flor Francisco José[2], Álvarez Domínguez Servando[1], Molina Félix Jose Luis[1], and Macias Olga[3]

1 University of Seville, Grupo de Termotecnia.C/ Avda de los Descubrimientos S/N.41092 Sevilla, Spain
2 University of Cadiz, Dpto. De Máquinas y Motores Térmicos.C/ Chile, 1. 11002 Cádiz, Spain
3 Tecnalia,Parque tecnológico de Bizkaia. E-48160 Vizcaya, Spain
**Corresponding author: jms@us.es*

ABSTRACT

The Spanish Technical Building Code is one of the three royal decrees that were approved in Spain as a consequence of the transposition of the European Directive on the energy performance of buildings (2002/91/EU) [1]. One basic document of the Technical Building Code deals with the limitations in the energy demand of buildings. Nowadays, due to the recast of the European Directive on the energy performance of buildings (2010/31/EU) [2], a revision process of the current regulations has begun, starting with the Technical Building Code, with its first revision envisaged for 2012. In this article we, as collaborators in this updating process, describe and analyse the main changes regarding ventilation and infiltrations that the updated Technical Building Code (TBC) is going to introduce. These main changes were classified in the next aspects, the calculation methodology, the ventilation technologies that can be considered, and the default values and the data that the user can supply to assess its particular case. The article compares the ventilation required in Spain with the mandatory values in other 16 European countries. Finally, the mean air infiltration values are compared to the values of the EN 15242:2007 [3] and to measured air infiltration values in actual Spanish dwellings.

KEYWORDS

Ventilation and infiltration regulations. Air flow rates. Calculation methods. Residential buildings.

INTRODUCTION

This article is going to classify the main changes that appear in the new Spanish regulation regarding ventilation and infiltration in the next topics:

1. Calculation methodology.
2. Ventilation technologies that can be considered.
3. Default values and data requested to the users.

Thus, these topics will be the three main sections of the present paper.

The objective of this paper is then to show how the regulation regarding ventilation and infiltration has been modified in one State Member of the European Union, Spain. Along the paper we will describe the criteria that have been followed to select the new specifications. Finally, we will comment the consequences of these modifications.

CALCULATION METHODOLOGY

Basically, the calculation methodologies regarding air flows implement a multi-zone loop method. Loop methods have been used extensively in the duct networks analysis. They provide an 'exact' analytical approach to size components of natural and hybrid ventilation systems and offer a number of advantages when compared to the node continuity methods [4]. On this basis we are going to describe the particularities of each regulation:

Former Regulation (2006)

The former regulation is based in the EN 13465:2004 [5], thus it implements a loop method with only one indoor pressure and one outdoor pressure by assuming that all the indoor spaces are a single-zone for single family houses and also for blocks of flats.
The Technical Building Code [6] establishes the ventilation rates for indoor air quality in the basic document HS3 on "indoor air quality", and also limits the infiltrations through windows in the basic document HE1 on "energy needs limitation".
Following the HS3 the inlet flows –bedrooms and living-room- and exhaust flows –bath-rooms and kitchen- should be calculated separately and consider the ventilation flow as the higher of both. For calculations the next table should be used:

Type of zone	Per occupant	Per square meter	Other
Bed-rooms	5	-	-
Living-rooms and dinning-rooms	3	-	-
Bath-rooms and toilets	-	-	15 per room
Kitchens	-	2	50 per room
Storage rooms	-	0.7	-
Parkings and garages	-	-	120 per place
Waste storage	-	10	-

Table 1. Minimum ventilation flows required (l/s).

These values can be compared with the ones in the table 1 of the article [7] by Dimitroulopoulou.
The maximum ventilation flow from inlet and exhaust flows is the one considered in a constant schedule of 24 hours a day. Next figure shows this schedule for a building where the maximum air flow is equal to 45 l/s.

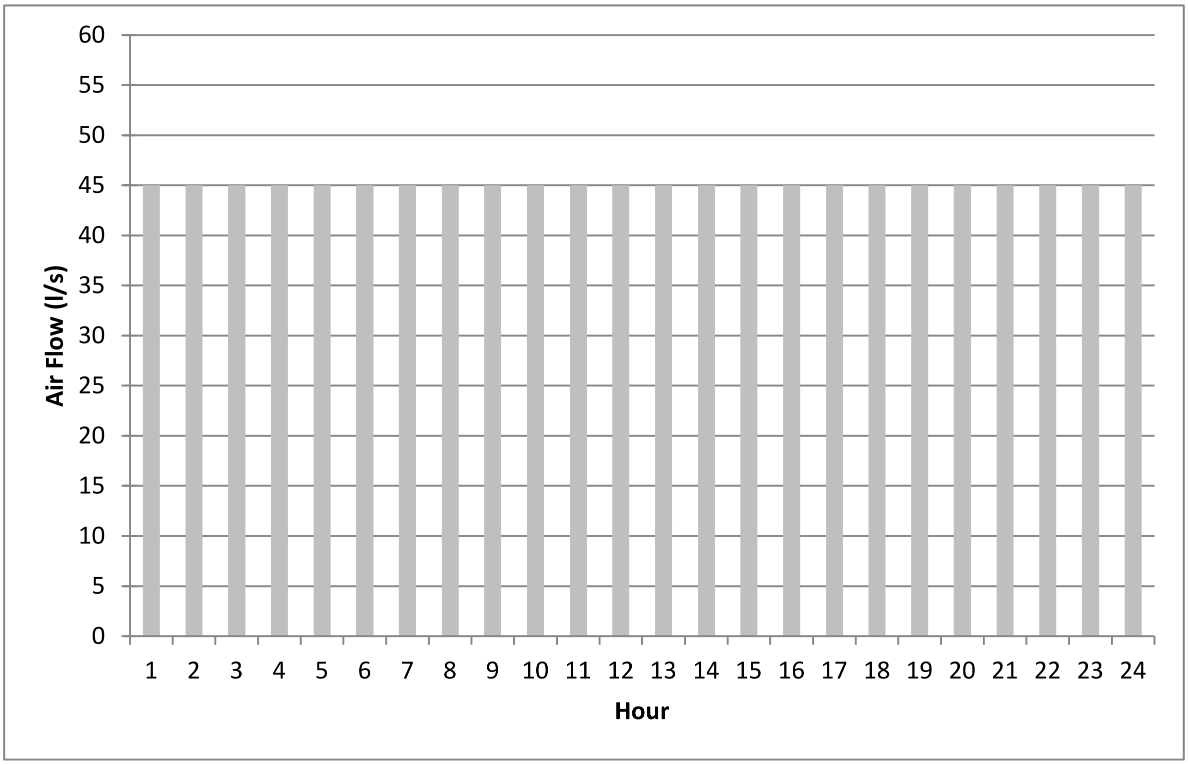

Figure 1. Standard supply air flow schedule.

The air flow of the extraction hood and the eventual air flow requirement of the domestic hot water boiler –or any combustion system- are not envisaged in this regulation.

In order to compare ventilation requirements in different countries, we calculated the same test cases than Brelih and Seppänen in [8]. These tests were developed for two different dwellings, a kitchen, a toilet, a bathroom, a school classroom, a kindergarten playroom, and an office. These cases are very interesting as they represent real-world situations. The authors include the results in 16 European countries, this, allowed us to situate the Spanish ventilation rates in this context. In conclusion, it can be said that in the dwellings the values for Spain are very compared to the average value in European countries. We analyzed the cases and we detected that the origin of this excess is the consideration of the maximum inlet and exhaust flows in the rooms.

The equations for the pressure losses in the cracks, windows and vents are the proposed in the European standard EN 13465:2004 [4].

The default values for the infiltration through opaque elements (cracks) are the next:

- 0.30 air changes per hour at 1 Pa in single-family dwellings. 0.76 at 4 Pa.
- 0.24 air changes per hour at 1 Pa in blocks of flats. 0.61 at 4 Pa.
- 0.10 air changes per hour at 1 Pa in other buildings (tertiary). 0.25 at 4 Pa.

These values are fixed and can not be changed by the building designer.
If we compare these values with the ones that appear in other regulations we can see that these one do not depend on the outdoor or exposed surface of the building like in the French Thermal Regulation [9], on the contrary these are constant values that only depend on the drop pressure between indoor and outdoor, they were obtained from the annex A (not mandatory), tables A.2 and A.3, of the EN 13465:2004 [5].

The permeability of windows is a data that the building designer can modify if the window has a certificate of permeability. The maximum values are 50 m^3/hm^2 at 100 Pa for the south of Spain, and 27 m^3/hm^2 at 100 Pa for the middle and north of Spain. The doors have an invariant permeability coefficient of 60 m^3/hm^2 at 100 Pa due to the absence of a certificate for these elements.

The vents are not defined by the user, they are sized by the official software of the Technical Building Code in order to ensure the air ventilation flow required.

New Regulation (2012)

The proposed new regulation uses the calculation methodology of the EN 15242:2007 [3]. This standard is an actualization of the former and derogated EN 13465:2004 [5]; it is also based on a loop method and keeps the calculation of air infiltrations trough opaque elements, windows and air vents. The novelty is the indoor zoning that allows calculating (using mass conservation laws) the air flow between zones in a similar way that software SIREN [10] does.

The minimum ventilation air flows are not going to be modified by the moment, but futures modifications are not discarded if the practice shows them to be inappropriate to ensure acceptable indoor air quality levels. One of the most important implications of the modification in the required air flow rates is that the energy labelling of a determined building would change as the energy performance scale of new and existing buildings defined in [11, 12] was done with the minimum air flows of the 2006 regulation. This modification in the energy labelling is difficult to justify because it would be a consequence of a change in the calculation methodology –required air flow rates- and not of an improvement of the methodology for the ventilation of the building or its systems or devices.

As referred in [8] lower air flows, in general, are not recommendable. However, the present values used in Spain and in several European countries are very high and a coincidence factor should be applied. As a consequence, a European harmonized regulation theoretically based is necessary.

Regarding indoor air quality, probably a performance-based criterion similar to France, Finland, Norway and Portugal regarding the CO_2 concentration will be used. In Spain, the regulations [13, 14] define the maximum difference between indoor and outdoor CO_2 concentration and the maximum CO_2 concentration in 600ppm and 2500 ppm respectively.

The novelty in the air flows is that the extraction hood in the kitchen is going to run two hours a day in order to take into account the real use of the system, the air flow requirements for combustion (for instance domestic hot water boiler) is going to be considered null because all the new boilers should be airtight.

The default values for the infiltration through opaque elements (cracks) have been changed to fit with the EN 15242:2007 that appeared after the publication of the 2006 regulation. In this standard the Table B.1 of the Annex B (normative) give three values for the permeability of the envelope depending on the air leakage level, in the next point we will justify why we have choose the highest level and thus the default values for the infiltration through opaque elements (cracks) have been fixed to 1.8 m^3/h per square meter of exposed wall surface for single-family dwellings and 1.95 m^3/h per square meter of exposed wall surface for blocks of flats.

As in the former regulation the permeability of windows will be a data that the building designer could modify if the window has a certificate of permeability. The maximum values probably will be more severe than the previous ones.

The software of application of the regulation will size the vents although it will allow to the designer to modify the type –different vent types are listed in the point titled “other energy saving measures”- and probably the nominal air flow in order to give more freedom for the different alternatives.

All these innovations allow to skip the negative effects of the assumptions done on the regulation of 2006: in first term because the calculation of the air flow between zones allows to assign the ventilation energy load to the exact zone that is receiving it, and keep it equal to zero in the zones that only receive the ventilation air from conditioned spaces. A second consequence of calculating the air flow between zones is that it is possible to define the ventilation strategy –demand controlled ventilation, heat recovery ventilation with double flux-. A third consequence is the elimination of a market barrier for the ventilation systems, because now if a designer has implemented a ventilation strategy it can be calculated and it is taken into account in the energy performance of the building, this is very important as the maturity of the ventilation sector is high and the solutions adopted were very basics due to the regulation. Finally, this new regulation open a door for improvements on the tightness of the new buildings as the permeability of the opaque elements is not a default value anymore and now this data that can be given by the designer after a permeability essay, for example a blower door test.

CRITERIA FOR THE NEW SPECIFICATIONS

The criteria for the new specifications have been to keep, when it is possible, the same mean values, updating the reference standards and allowing to the designer a highest degree of freedom in his decisions.

In this sense the main change in the default values have been the change in the opaque permeability value, because is has been moved from a fixed value in air changes per hour –Annex A of EN 13465:2004- to a variable (per square meter of outdoor surface) value from Annex B of EN 15242:2007.
In this section we will explain how we have converted the former values in the new ones keeping the same mean values.

If we compare the values of the EN 13465:2004 with the ones in the EN 15242:2007 there are two main differences: both values are not in homogeneous units -air changes per hour vs. m^3/h per square meter of exposed wall surface-; on the other hand the values of the first standard are referred to the air flow through opaque elements of the building envelope (cracks), while the values of the second one are referred to air infiltration through the whole envelope including opaque elements and window voids.

What we have done is to convert the former regulation values based on the EN13465:2004 into a value comparable to the values of the EN 15242:2007. In order to do that first of all we will multiply the original values with the ratio volume/area of exposed wall surface, thus we will obtain the infiltration through cracks in m^3/h per square meter of envelope surface. After this we will add to this air flow the infiltration through windows using the next equation:

$$Q[m^3/hm^2] = q_{4Pa}^{opaque} \cdot \frac{V}{A^{env}} + perm_{100Pa}^{window} \cdot \left(\frac{4}{100}\right)^{0.67} \cdot \frac{A_{window}}{A^{env}} \qquad (1)$$

Where:

$q_{4Pa}^{opaque}[1/h]$: is the infiltration flow through opaque elements at 4 Pa. The normative value following the former regulation is 0.76 for single-family dwellings.
$perm_{100Pa}^{window}[m^3/hm^2_{window}]$: is the window permeability at 100 Pa.
$\frac{V}{A^{env}}[m^3/m^2]$: is the ratio volume/area of envelope surface.
$\frac{A_{window}}{A^{env}}[m^2_{window}/m^2]$: is the ratio window area/area of envelope surface.

Last two parameters depends on the geometry of the building, next tables gives representative values of this for typical constructions in Spain.

Type of building	$\frac{V}{A_{cv}^{exp}}[m^3/m^2]$	$\frac{A_{vent}}{A_{cv}^{exp}}[m^2_{vent}/m^2]$
Single-family dwellings	2.13	0.093
Blocks of flats	3.56	0.138

Table 5. Mean values for the ratios in single-family dwellings and blocks of flats.

The resulting air flow Q is comparable to the EN 15242:2007 because now it includes the same infiltration flows and due to the congruency of unit system. Next table gives the mean values obtained:

Type of building	$Q[m^3/hm^2]$
Single-family dwellings	2.01
Blocks of flats	2.72

Table 6. Mean values for air infiltration flow in single-family dwellings and blocks of flats.

The conclusion of the comparison is that these values are around the maximum value given by the European standard –for the highest level of leakage- that is 2 m^3/h per square meter of envelope surface. Thus we have assumed this figure as the new air infiltration flow in the new regulation. The permeability of opaque elements at 4 Pa that corresponds to this value is 1.6 m^3/h per square meter of envelope surface, this give 1.8 m^3/h per square meter of exposed wall surface –without window voids- for single-family dwellings and 1.95 in the same units for blocks of flats.

Experimental data

In Spain, there are few data about field measurements of the tightness of building envelope, so it becomes difficult to adjust normative with experimental values.

Most of the existing field data corresponds to residential buildings from a region of the north of Spain (Basque Country). Derived from European Directive 93/76/CEE (SAVE), CADEM entity, which belongs to Basque Energy Agency, implanted a voluntary energy certification system for buildings where field tests such as Blower Door Test are mandatory in order to obtain the real energy performance of the certified buildings.

Data provided by CADEM about Definitive Energy Certificates given until June 2010 were:

No. promotions	No. dwellings	Energy savings (Toe)
≈ 200[1]	≈ 13.000	≈ 7.000

Table 7. Data about energy certificates in the Basque Country region.

Since 1994 until 2010 there were carried out about 600 airtightness tests. These field measurement of aightightness were fulfilled following European Standard EN 13829 [15] (previosly International Standard ISO 9972)

There are not accurate stadistical data, but a general relation between air leakage rates and definitive energy rate is observed.

In general, the average air leakage rates obtained from blower door test at 4 Pa for buildings that were certified with highest rate, A, are closed to 0,35-0,40 h^{-1}, whereas for buildings certified with C rate, the average air leakage values are closed to 0,60-0,65 $^{h-1}$.

Energy rating	Air leakage rate at 4 Pa	Air leakage rate at 50 Pa
A	0,35 – 0,40	1,9 – 2,2
C	0,60 – 0,65	3,3 – 3,6

Table 8. Typical air leakage values for A and C energy labelled dwellings.

Comparing Spanish air leakage rates with Dutch data provided by TNO [16] it is possible to conclude that Spanish buildings certified with C energy rate present similar aightightness values than Dutch constructions in 1990, whereas most efficient buildings certified with A get air leakage rates similar to Dutch buildings in 2005.

VENTILATION TECHNOLOGIES

The calculation methodology implemented for the new regulations (2012) allows calculating the outdoor air that gets into the building through the walls (infiltrations), through the windows (infiltrations) and through the specific vents designed for the ventilation purposes. Also the methodology allows following the path of the air assessing the air flow from the inlet zones to the corridor and from there to the exhaust zones (bath-rooms).
Thus this methodology is useful for calculating the next systems:

- Demand controlled ventilation: there are two levels of this technology:
    - Basic: In this case the maximum air flow would be used when the bath-rooms are in use (3 hours a day), and the rest of the time the required air flow would be equal to the minimum.

[1] In each promotion (one promotion corresponds to one energy certificate) an average of three airtightness tests were carried out.

- Advanced: In this case the air flow rate would be the necessary for the occupation hour by hour.

- Double-flux (balanced) system, this system includes a duct network for the inlet and exhaust air flows, so it is possible to pre-heat the inlet air with the exhaust flow. This system includes the installation of a heat recovery unit as exchange unit.

- Combinations of demand controlled ventilation and heat recovery systems.

The technology required for the basic level of demand controlled ventilation consist on presence sensors in the bath-rooms, a double speed exhaust fan and a control device that connect the sensors with the fan. Figure 2 shows the supply air flow hour by hour.

The technology required for the advanced level consist on presence sensors in all the rooms, a multi-speed exhaust fan –it is possible to have more than 6 air flows depending on the number of rooms of the dwelling and the occupancy-, controlled air vents in all the inlet zones –bedrooms and living-room- and an advanced control device that connect all the elements of the system. Figure 4 shows the supply air flow hour by hour.

The previous technologies are based on the presence; alternatively, strategies based on the relative humidity, CO_2 concentration can be used. They are described for residential buildings in [17, 18, 19].

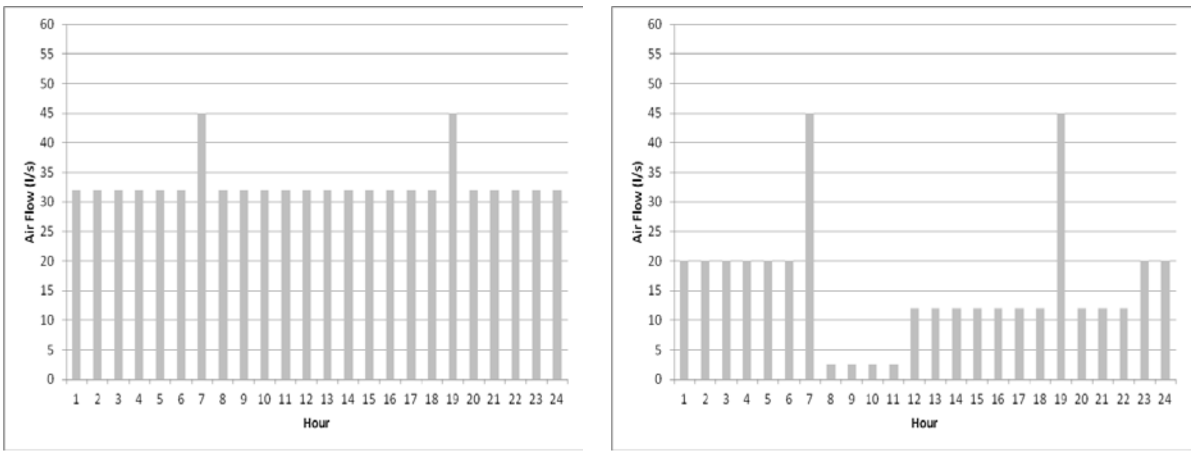

Figure 4. Left: Supply air flow schedule for the basic level of demand controlled ventilation. Right: Supply air flow schedule for the advanced level of demand controlled ventilation.

OTHER ENERGY SAVING MEASURES

Also the new regulation allows calculating the influence of the next energy saving measures in the energy demand:

- Use of self-regulating vents.
- Use of non-return self-regulating vents.
- Use of hygro-regulating vents.
- Improve of the air tightness of opaque elements.
- Improve of the air tightness of windows.

The market of the vents for ventilation is mature and has certain products that could help to improve the energy demand. The former regulation does not give any improved value if the designer chooses one of these products. The new regulation will change the situation giving simulation software that allows calculating the energy consumption and the indoor air quality when using different kinds of vents.

The air tightness of opaque elements is a default value that the designer could not change, but also if a special attention has been put in the construction using vapour barrier and membrane of air tightness for the walls, and using sealants products, silicones, foams or polyethylene tapes for the junction of the walls with the windows or doors openings, the designer could make a permeability test and use the result of this as a input for the software.

The air tightness of windows is a variable value that the designer can move to fulfil with the requirements of the Technical Building Code and also to improve the energy demand or IAQ results.

CONCLUSIONS

The basic documents of the Technical Building Code have to be updated periodically. These actualizations can be motivated for obsolete standards or for the need of contemplate and assess the effect of using certain technologies that previous versions do not deals with. This is the case of the basic document of energy limitation and it relation to the basic document regarding indoor air quality.

Present document shows how we have updated the references to derogated standards using new ones, and simultaneously keeping the congruence of the default values. Also we have used new simulation methodologies that allows to assess the effect of implement a higher number of ventilation technologies.

Basically we have produced a new regulation that assumes one indoor pressure and one outdoor pressure (calculation methodology EN 15242:2007). But keeping and indoor zoning that allows calculating (using mass conservation) the air flow between zones. The calculation methodology permits the possibility of using a control system allowing different flows each hour for a demand controlled ventilation scheme and pre-heating of supply air flow. And finally the new regulation is flexible to allow sizing the vents, using self-regulating vents or changing the permeability of opaque elements, for example if a blower-door test has been carried out. As a consequence the standard will not be a market barrier and promote the use of technologies of ventilation in order to improve the energy efficiency of buildings.

ACKNOWLEDGEMENTS

The data about energy certificates and air leakage in existing dwellings were provided by CADEM, the authors would like to acknowledge this contribution.

REFERENCES

[1] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings. Official Journal of European Communities.

[2] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings. Official Journal of European Union.

[3] EN 15242:2007. Building ventilation. Methods for the assessment of the air flow rates in buildings, including infiltrations. European Committee for Normalization. 2007.

[4] Building Ventilation, the state of the art, Santamouris M., Wouters P., Earthscan, London, Sterling, VA, 2006. Chapter 2 by Axley J.

[5] EN 13465:2004. Building ventilation. Methods for the assessment of the air flow in dwellings. European Committee for Normalization. 2004.

[6] Royal Decree 314/2006, passing the technical building code (Código Técnico de la Edificación). Spanish Official Journal (BOE) 74. March 2006. http://www.codigotecnico.org/web/recursos/aplicaciones/contenido/texto_0002.html. Basic Document HE-1 Energy needs limitation. Basic Document HS-3 Ventilation and Indoor Air Quality.

[7] C. Dimitroulopoulou, "Ventilation in European dwellings: A review", Building and Environment, vol. 47, pp. 109-125, January 2012.

[8] N. Brelih, O. Sepänen, "Ventilation rates and IAQ in European Standards and national regulations", 32nd AIVC Conference and 1st Tightvent Conference, Brussels, October 2011.

[9] Reglementation Thermique, Guide réglementaire. CSTB. 2010.

[10] Logiciel SIREN. Simulation de renouvellement d'air. CSTB.

[11] Royal Decree 47/2007, approving the Basic Procedure to certify energy efficiency in new-construction buildings. January 2007. http://www.minetur.gob.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/ProgramaCalener/Paginas/DocumentosReconocidos.aspx

[12] Royal Decree XX/2012, approving the Basic Procedure to certify energy efficiency in existing buildings. Public audience until April 2012. http://www.minetur.gob.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/propuestaNuevosReconocidos/Paginas/nuevos.aspx

[13] EN 13779:2007 Ventilation for non-residential buildings. Performance requirement for ventilation and room-conditioning systems. CEN, 2007.

[14] NTP 549. Carbon dioxide in the IAQ evaluation, National Institute for Occupational Safety and Health at Work. El dióxido de carbono en la evaluación de la calidad del aire interior. Instituto Nacional de Seguridad e Higiene en el Trabajo.

[15] EN 13829:2002, Erratum 2010 Thermal performance of buildings. Determination of air permeabilityu of buildings. Fan pressurization method. (ISO 9972:1996, modified). CEN, 2002-2010.

[16] W. de Gids, Optimal Air Tightness Levels of Buildings. Session 5B: Philosophy for defining airtightness requirements.TIGHTVENT Conference, Brussels, 2011.

[17] T.R. Nielsen, C. Drivsholm, "Energy efficient demand controlled ventilation in single family houses", Energy and buildings, Vol. 42, pp. 1995-1998, 2010.

[18] J. Laverge, N. van den Bossche, N. Heijmans, A. janssens, "Energy saving potential and repercussions on indoor air quality of demand controlled residential ventilation strategies", Building and environment, Vol. 46, pp. 1497-1503, 2011

[19] D. Johansson, H. Bagge, L. Lindstrii, "Measurements of occupancy levels in multi-family dwellings-Application to demand controlled ventilation", Energy and buildings, Vol. 43, pp. 2449-2455, 2011.