Standards for Ventilation and Indoor Air Quality in relation to the EPBD

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Introduction

Ambient (outdoor) air quality in cities in industrialized countries has improved greatly in recent decades. During this same period, indoor air quality has declined because of energy conservation, decreased ventilation and the introduction of many new materials and sources of indoor pollution. These developments and the fact that people in industrialized countries spend 90% of their lives indoors on average makes the quality of indoor air an important environmental issue with far-reaching implications for human health. Allergic and asthmatic diseases have doubled in industrialized countries during the past two decades. They comprise one of the greatest current problems for public health, with enormous costs for medicine, treatment and absenteeism. In many industrialized countries, half the schoolchildren suffer from these allergic diseases, which are the main reason for absenteeism in schools.

Indoor air quality has declined partly because of comprehensive energy conservation campaigns and partly because high energy prices have motivated people to tighten their dwellings and reduce the rate of ventilation, so that the air change rate in many homes is at a historically low level. Other factors contributing to poor indoor air quality are the many new materials, especially polymers, and the numerous electronic devices that have been introduced indoors in recent decades, especially in children's rooms.

Today an acceptable indoor air quality is mainly defined by specifying the required level of ventilation in air changes per hour or the outside air supply rate. This would be equivalent to defining the requirements for thermal comfort by specifying the level of heating or cooling in Watts. The increasing societal need for energy efficiency will often result in very tight buildings. This means that the amount of outside air supplied by infiltration is not enough to provide the required ventilation. As the heat exchange with the outside due to transmission is decreasing by increased requirements to the building facades the energy required for ventilation (fans, pre-heating and pre-cooling of supply air) is percentagewise becoming a bigger and bigger part of the total energy use in buildings.

CEN standards related to ventilation of buildings

The calculation of influence of the ventilation system on the energy performance of buildings is mainly related to the following standards:

- EN ISO 13790: Energy performance of buildings - Calculation of energy use for space heating and cooling
- EN 15251: Indoor environmental input parameters for design and assessment of energy performance of buildings - addressing indoor air quality, thermal environment, lighting and acoustics
- EN 13779: Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems

- EN 15241: Calculation methods for energy losses due to ventilation and infiltration
- EN15242: Calculation methods for the determination of air flow rates in buildings including infiltration

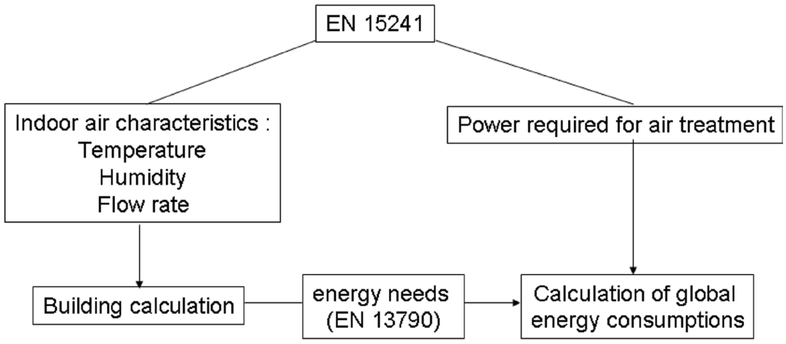

***Figure 1.** Basic principles of the use of EN15241 in relation to EN13790*

First of all the energy demand for ventilation is calculated by EN13790 as a building characteristic taking into account the required indoor environment (ventilation rates from EN15215 or infiltration rates from EN15242).

In EN 15242 the air flows are calculated both for mechanical, hybrid and passive ventilation. The calculation for mechanical systems is based on the required air flows from EN15251/EN13799. The values are corrected to take into account factors like: position of the air handling unit (indoor or outdoor), the switching on-off, **ventilation effectiveness**, accuracy of the system design, air flow through duct leakages, air leakages of the air handling unit and air recirculation, if any. For passive and hybrid duct ventilation the aim of the calculation is to calculate the air flow in the system taking into account the outdoor and the indoor conditions. The method provides the relationship between the air velocity in the duct and the pressure loss through the cowl which depend on the outside weather conditions taking into account, wind air velocity outside the building, pressure loss coefficient of the cowl, roof angle and the position of the cowl.

The energy need for a ventilation system can then be calculated according to EN15241 taking into account energy needs for fans, pre-heating, pre-cooling, efficiency of heat exchangers, humidification, dehumidification and energy losses in ducts. The overall principle is shown in **figure 1.**

An important issue is the boundary between EN13790 and EN 15241 to avoid calculation the effect of the same measure twice (heat recovery). Specific design guidelines and requirements to ventilation systems are listed in EN13799. The guidance for design given in this standard and its annexes are mainly applicable to mechanical supply and exhaust ventilation systems, and the mechanical part of hybrid ventilation systems.

Applications for residential ventilation are not dealt with in this standard. Performance of ventilation systems in residential buildings are dealt with in CEN/TR 14788. The classification uses different categories. For some values, examples are given and, for requirements, typical ranges with default values are presented. The default values given in this standard are not normative as such, and should be used where no other values are specified. Annex A gives guidelines established for mechanical ventilation and air-conditioning systems for building subject to human occupancy. The user will find there some design values and recommendations (for proper consideration of outdoor air quality, selection of air filters and heat recovery) to set up the appropriate ventilation system on the building.

Annex B is a guideline for economic aspects, which explains the basis of the present value method to evaluate the net present cost of a certain investment. It refers to another standard for details. This may in a future revision be deleted as a separate standard for economical calculations exist.

Methods for specifying required ventilation rates

Both people and building-related sources of pollution are taken into account in newer standards for the required ventilation rates in buildings, which include ASHRAE 62.1 [1], and EN15251. The standards include a prescriptive method, where the minimum ventilation rates can be found in a table listing values for different types of space. All of the proposed standards deal with the health issue and as well as the comfort issue.

Prescriptive procedure

For the prescriptive method, a minimum ventilation rate per person and a minimum ventilation rate per square metre floor area are required. The two ventilation rates are then added. The person-related ventilation rate should take care of pollution emitted from the person (odour and other bio effluents) and the ventilation rate based on the floor area should cover emissions from the building, furnishing, HVAC system, etc.

The design outdoor airflow required in the breathing zone of the occupied space or spaces in a zone, i.e., the breathing zone outdoor airflow (V_{bz}), is determined in accordance with the equation:

$$V_{bz} = R_p P_z + R_a A_z \qquad (1)$$

Where: A_z = Floor area; P_z = Occupant density; R_p = Outdoor airflow rate required per person; R_a = Outdoor airflow rate required per unit floor area.

As a minimum it must be ventilated to dilute the bio effluents from the occupants (people component, R_p, see **table 1**). These rates are in EN15251 specified for three categories of indoor air quality, based on the prediction that a certain **percentage of visitors** will find the air quality unacceptable. The design levels are thus adequate for people who walk into a space. It is debatable if this should always be the case. People adapt very quickly to the odour (bioeffluents) in a space while there is less adaption to emissions from building materials and tobacco smoke (odour and irritants, [2]). To provide an acceptable perceived air quality for occupants (who have adapted to the air quality for at least 15 min.) it is estimated that one third of the ventilation rate is sufficient i.e. for category II 2,5 instead of 7 l/s per person. ASHRAE Standard 62.1 for ventilation and indoor air quality defines ventilation levels for adapted persons (occupants). In addition, the minimum recommended ventilation is increased with a building-related ventilation rate, in order to take into account the emissions from the building and its systems (see **table 1**). Several studies indicate that adding the sources and ventilation rates is the best approximation, but it may not be valid for all types of pollutants. Here it is the contribution to the odour and irritation (perceived air quality) which must be taken into account. So it can be argued they all influence one organ (the nose) and so should be added. When the health risk is considered a simple addition can only be made for the same chemical component.

Table 1 shows the required ventilation rates from standard EN15251 compared to ASHRAE 62.1. There are quite big differences between the European recommendations and those listed by ASHRAE. One major reason is that ASHRAE requirements are minimum code requirements, where the basis for design is adapted people, while the European recommendations are for un-adapted people (visitors).

Ventilation effectiveness

The ventilation rates specified in the standards (**table 1**) are the required rates at breathing level in the occupied zone. The required ventilation rate at the room supply diffusers are calculated as:

$$\text{Total ventilation rate } V = V_{bz} / \varepsilon_v \qquad (2)$$

Where: V_{bz} = breathing zone ventilation, ε_v = Ventilation effectiveness

The ventilation effectiveness depends on the air distribution efficiency and the type and position of the pollution source(s), so this value is not only a system characteristic. In most cases it is assumed that the pollutant emission is uniform, so the ventilation effectiveness is the same as the air distribution effectiveness. For a fully-mixed ventilation system the value is 1 and the ventilation rates in **table 1** can be used for the design of the supply grills. The ventilation effectiveness or air distribution efficiency is a function of the position and type of supply and return grills, and depends on the difference between supply and room temperature and on the total amount of airflow through the supply grill. The air distribution effectiveness can be calculated numerically or measured experimentally. For displacement and personal ventilation the values may be higher than

Table 1. Smoking free spaces in commercial buildings according to ASHRAE 62.1 and EN15251

Type of space	Occupancy person/m²	Category CEN	Minimum ventilation rate, i.e. for occupants only l/s person		Additional ventilation for building (add only one) l/s·m²				Total l/s·m²	
			ASHRAE R_p	CEN	CEN Very low-pollut.	CEN Low-pollut.	CEN Not low-pollut.	ASHRAE R_a	CEN Low Pol.	ASHRAE
Single office (cellular office)	0,1	I	2,5	10	10	1,0	2,0	0,3	2	0,55
		II		7	7	0,7	1,4		1,4	
		III		4	4	0,4	0,8		0,8	
Conference room	0,5	I	2,5	10	10	1,0	2,0	0,3	6	1,55
		II		7	7	0,7	1,4		4,2	
		III		4	4	0,4	0,8		2,4	

1; but if warm air is supplied to a space the values may be as low as 0,5.

The air distribution effectiveness takes into account the air distribution in a space, but does not take into account how effectively the outside air is transported through the ducts to the space. If the system has any air leakage, the amount of ventilation air must be increased. This is not dealt with in EN15251, but is mentioned in ASHRAE 62.1.

Discussion

Even if we today have standards and guidelines for estimating the required minimum ventilation rate, they are far from being complete. The goal is of course to be able to calculate the required ventilation rate as straightforwardly as in cooling load calculations. We need to know the requirements for acceptable indoor air quality based on health, comfort and performance and we need to know the emission rates from all the sources. Unfortunately, this is not as easy as in cooling load calculations, where room and outside temperature (°C), energy emission (watts), heat storage, solar radiation (watts) are all evaluated with similar units and all affect the same parameter of the human body (heat balance). For indoor air quality, we have thousand of substances that are emitted from people, furnishing, systems, from outside etc., each of which may affect one or more organs of the body.

There is general agreement that when specifying the minimum ventilation rate both the "pollutant" contributions from people (and their activity) and from the "building (furnishing, building materials, HVAC systems) must be taken into account. And as the emissions from both types of sources influence the odour level (as detected by the nose) we should add the contributions and the ventilation rates, just as when there are 5 occupants you must provide 5 times the ventilation rate for one person. The difference is that the perception of the occupants cannot be added linearly, so that when doubling the sources one should not expect the number of occupants dissatisfied to double. This is the case when comfort is the main criteria. If we consider health the emissions from different sources may influence different organs so if you ventilate for one substance you will also dilute another. In most cases the comfort requirements (odour) will lead to the highest minimum ventilation rate. We have good knowledge about the required ventilation for the "people" component, while the "building" component is not very well documented. There is an urgent need for better certification and labeling of the materials used in buildings and we must also develop ventilation standards that favor the manufacturers of "good" (low polluting) materials. A start has been made by defining three types of buildings in EN15251, but the method for evaluating to which type an existing or projected building should belong is not good enough.

Who should we ventilate for? For people just entering the room (un-adapted) or for people already occupying a room (adapted)? Here the philosophy adopted by ASHRAE 62.1 and EN15251 differs. But should it really be one or the other? In a conference room, auditorium or lecture room most people enter at the same time. It then takes some time before the odour level has reached an unacceptable level and meanwhile people adapt. In this case it may be appropriate to require a ventilation rate based on adapted persons. There may be other spaces where you would design for un-adapted people, e.g. in a first class restaurant, offices, and department stores. It seems logical that more differentiated criteria could be used. The rates given in the Tables are based on full mixing and in practice the ventilation effectiveness is very seldom taken into account. One complication is that some systems may have a different ventilation effectiveness summer and winter. If the supply temperature is lower than room temperature the ventilation effectiveness is normally 1 or higher, but if the ventilation system is used for heating in winter the ventilation effectiveness could be as low as 0.5, and the ventilation rates should really be doubled. More information and a greater emphasis on this factor are required. Air cleaning is not taken into account at all in EN15251, while ASHRAE 62.1 by using the analytical procedure can allow some credits for air cleaning. There is an increased interest in the development of air cleaning equipment. This may be an acceptable way of reducing the amount of outside air, saving energy and still having an acceptable indoor air quality. However, better test methods for air cleaners are required, because at present the test is usually based on chemical measurements and the resulting effect on odour or perceived air quality is not taken into account. It is also very important to specify which kind of "pollutants" should be used when testing. Some air cleaners may work well on VOC's (emission from materials) but have zero or even a negative effect if the source is people (bioeffluents).

References

1. *ASHRAE 62.1 (2007) Ventilation for acceptable indoor air quality, Atlanta, GA, American Society of Heating, Refrigerating and Air-Conditioning Engineers.*
2. *Gunnarsen, L., Fanger, P.O. (1992) "Adaptation to indoor air pollution", Environment International, 18:43-54.*