International standards for the indoor environment. Where are we and do they apply to Asian countries?

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ABSTRACT

On the international level, ISO (International Organization for Standardization), CEN (European Committee for Standardization) and ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) are writing and reviewing standards relating to the indoor environment on a regular basis. This presentation will focus on the development of standards for the indoor thermal environment and indoor air quality (ventilation).

In the future, recommendations for acceptable indoor environments will be specified as classes. This allows for national differences in the requirements as well as for designing buildings for different quality levels. Several of these standards have been developed mainly by experts from Europe, North America and Japan. Are there, however, special considerations relating to South-East Asia (lifestyle, outdoor climate, economy) that are not dealt with in these standards and that will require the revision of existing standards? Critical issues are adaptation, the effect of increased air velocity, humidity, type of indoor pollutant sources, etc.

The paper will present an overview of existing methods and discuss areas where revision of present standards or the development of new standards are needed, relating especially to conditions in Asia.

INDEX TERMS

Perceived air quality; Ventilation rate; PMV; Thermal comfort; International standards

INTRODUCTION

The main purpose of most buildings and installed heating and air-conditioning systems is to provide an environment that is acceptable and does not impair health and performance of the occupants. Knowledge concerning the thermal climate parameters, their influence on the occupants and the influence of buildings and systems on these parameters is today relatively well known and established in international standards. Issues such as the comfort problems or benefits of increased air velocity, humidity and thermal comfort, whether people can adapt to accepting higher indoor temperatures during summer in naturally ventilated (free running) buildings, and a proposal for a whole-year evaluation of the indoor thermal environment are being discussed and included in the revision of international standards, e.g. ISO 7730rev (2003) and ASHRAE Standard-55-1992rev (2003). After the latest revision, these two standards for thermal comfort are now very similar.

Even though the last 15 years of research on indoor air quality has established a lot of new information, it has still not been possible to agree on one international standard. In most existing standards or guidelines for indoor air quality, the criteria or requirements have been given as ventilation rates. The most internationally used standard for ventilation and indoor air quality is ASHRAE Standard 62.1 (2003).

New concepts have been introduced in a European Technical Report, CR1752 (1998), where criteria for indoor air quality, ventilation, thermal comfort and noise are included. First of all, recommendations for an acceptable indoor environment are specified as classes. This allows for national differences in the requirements and also for designing buildings for different quality levels. This will also require a better dialogue between the client (builder, owner) and the designer.

CRITERIA FOR THERMAL COMFORT

The environmental parameters that constitute the thermal environment are: temperature (air, radiant, surface), humidity, air velocity and personal parameters (clothing together with activity level). Criteria for an acceptable thermal climate are specified as requirements for general thermal comfort [PMV-PPD or operative temperature (air temperature and mean radiant temperature), air velocity, humidity] and for local thermal discomfort [draught (mean air velocity, turbulence intensity, air temperature), vertical air temperature differences, radiant temperature asymmetry, surface temperature of the floor]. Such requirements can be found in standards and guidelines such as EN ISO 7730, CR 1752 and ASHRAE 55.

For most thermal parameters it has been possible to establish a relationship between the parameter and a predicted percentage of people finding the conditions unacceptable. People may be dissatisfied due to general thermal comfort (PMV, operative temperature) and/or dissatisfied due to local thermal comfort parameters (draught, radiant asymmetry, etc). Today no method exists for combining these percentages of dissatisfied persons to give a good prediction of the total number of persons finding the environment unacceptable. The level of thermal comfort chosen may be influenced by what is technically possible, economy, energy use, environmental pollution and performance. Therefore it is suggested in the revision of ISO EN 7730 that different levels of acceptance be specified, similar to CR 1752. Individual countries or a contract between client and designer can then specify which levels must be used. Table 1 gives recommended levels of acceptance for three classes of environment.

Table 1 Three categories of thermal environment. Percentage of dissatisfied due to general comfort and local discomfort (CR 1752, 1998)

Category	Thermal state of the body as a whole		Local thermal discomfort			
	PPD (%)	Predicted mean vote	Draught Rate, DR (%)	Vertical air temperature difference (%)	Warm or cool floor (%)	Radiant temperature asymmetry (%)
A	<6	–0.2 < PMV < + 0.2	<15	<3	<10	<5
B	<10	–0.5 < PMV < + 0.5	<20	<5	<10	<5
C	<15	0.7 < PMV < + 0.7	<25	<10	<15	<10

For general thermal comfort (operative temperature) and air velocity the corresponding criteria for the three classes are listed in Annex 1 for several typical spaces. The optimal temperature is the same for all three classes but the acceptable range will change. For the design of heating systems and heat load calculations the lower value in the range should be used, and for cooling, the upper value. A lower class then means the HVAC-equipment can be sized smaller and requirements to room temperature control is less stringent.

The criteria based on the three classes in Table 1 are listed in Table 2 for the other local discomfort parameters (radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures).

Table 2 Recommended categories for local thermal discomfort parameters

Category	Vertical air temp. diff. (K)	Floor surface temperature (°C)	Radiant temperature asymmetry (K)			
			Warm ceiling	Cool ceiling	Cool wall	Warm wall
A	<2	19–29	<5	<14	<10	<23
B	<3	19–29	<5	<14	<10	<23
C	<4	17–31	<7	<18	<13	<35

Some of the classes for local thermal comfort are similar because the existing data do not support even lower limits that are even lower.

Air Velocity

The air velocity in a space can lead to draught sensation, but may also lead to improved comfort under warm conditions. The draught model, which is included both in ASHRAE Standard 55 and in ISO EN 7730, is listed below:

$$DR = ((34 - t_a)*(v - 0.05)^{0.62})*(0.37*v*Tu+3.14)$$

where:
DR is the draught rating, i.e. the percentage of people dissatisfied due to draught;
t_a is the local air temperature in °C;
v is the local mean air velocity in m/s; and
Tu is the local turbulence intensity in per cent.

Recent studies by Griefahn (2000) indicate that this model must be modified to take length of exposure and activity level into account. Studies by Toftum *et al.* (Toftum and Nielsen, 1996a,b; Toftum *et al.*, 1997; Toftum and Melikov, 2000) show an additional influence of the velocity directions. The two studies do not agree completely with the above draught model. According to Griefahn, the models predict DR percentages that are too low, while according to Toftum *et al.*, they predict values that are too high.

ASHRAE standard 55rev and ISO-7730rev. include a diagram to estimate the air speed required to offset an increase in temperature (Figure 1). Toftum and Melikov (2000) experimentally verified the diagram (Figure 1) for occupants having individual control (ceiling fans, openable windows). This study also showed that the requirement for personal control (open windows, personal fans) of the increased air speed is essential for acceptance. Therefore, it may not be appropriate to offset a temperature increase by increasing the air speed within a centrally controlled air system. In this case, the requirements for draught must be used.

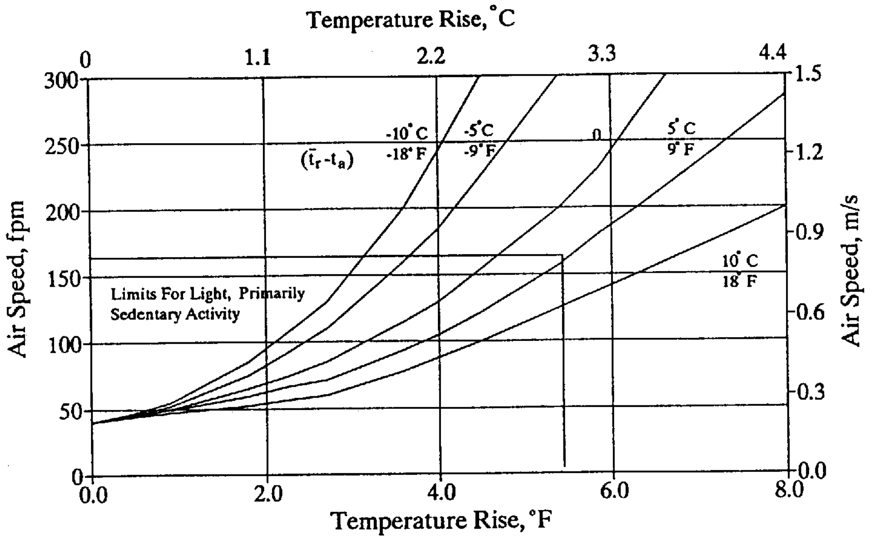

Figure 1 Air speed required to offset increased temperature (reproduced from ASHRAE standard 55-1992rev). The air speed increases by the amount necessary to maintain the same total heat transfer from the skin. Acceptance of the increased air speed requires occupant control of the local air speed.

Adaptation

The above-mentioned requirements are based mainly on laboratory studies with test subjects mainly from Europe and North America. But studies with Asian and African subjects (Fanger, 1973; Tanabe, 1987; de Dear, 1991) under laboratory test conditions have found similar results for general thermal comfort. Several extensive field studies summarized by de Dear and Brager (1998) show that in buildings with HVAC systems, the PMV model works well (Figure 2). The studies also show that in naturally ventilated buildings (free running, no mechanical cooling) people seem to adapt (behaviourally, psychologically) and can accept higher indoor temperatures than those predicted by the PMV model. In the revision of both EN ISO 7730rev and ASHRAE 55-92, it is being discussed how these results can be integrated in the standards. Whether people will still have the same level of performance at the higher temperatures is a further consideration.

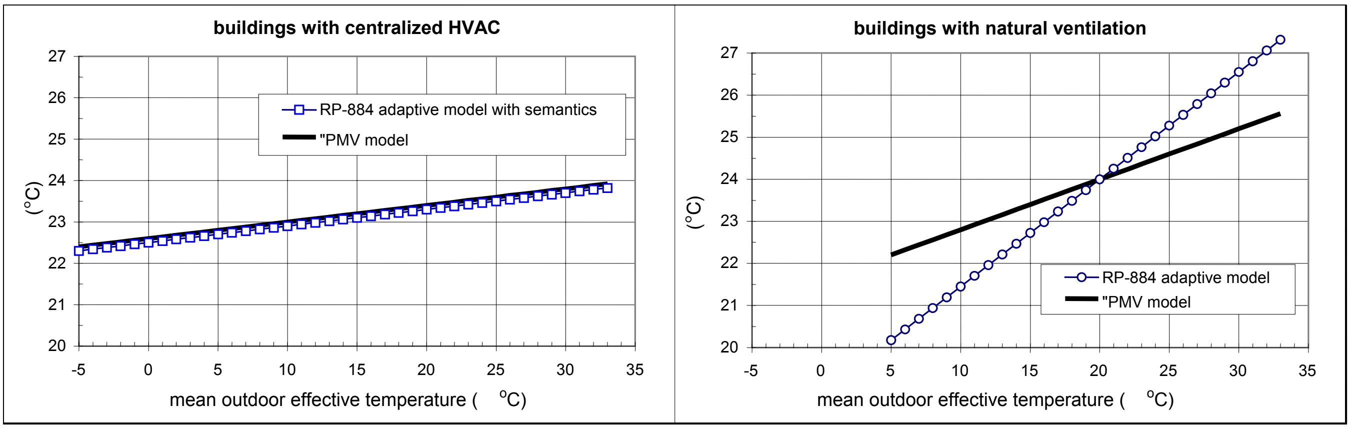

Figure 2 Comparison of the RP-884 adaptive models' predicted indoor comfort temperatures with those predicted by the PMV model (de Dear and Brager, 1998).

The implication of this adaptive model is shown in Figure 3 for different climate zones. It is important to emphasize that the climatic data used are those of the monthly average outside air temperature. For most European cities the upper limit is 26–27°C, which is similar to the recommended limits based on the PMV-PPD index (Annex 1). For warmer environments, however, it will be acceptable, according to this model, to have indoor temperatures that are some degrees higher. A question is if you have air conditioning at home, will you then also adapt to higher temperatures in your office?

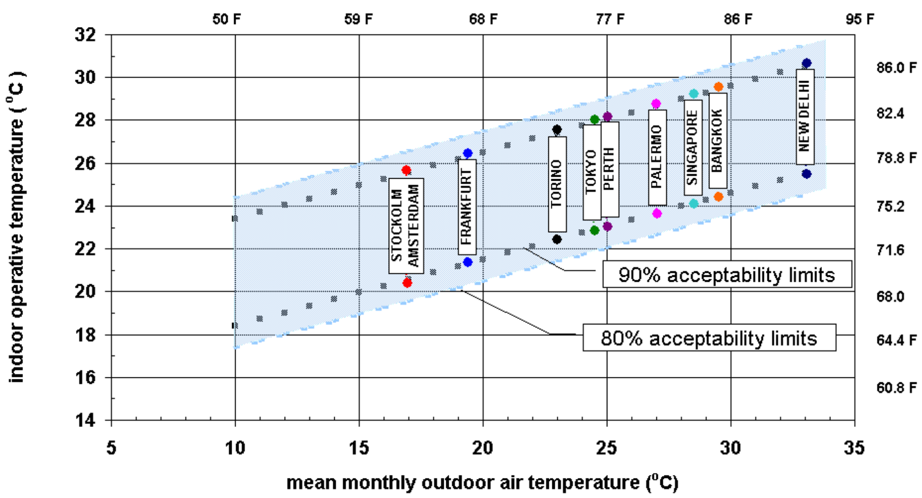

Figure 3 Acceptable operative temperature ranges for naturally conditioned spaces according to ASHRAE 55rev.-2003. Range shown for different climatic areas.

Humidity

The influence of humidity on the preferred ambient temperature is relatively small in the comfort range (EN ISO 7730, ASHRAE-55-92). Requirements for acceptable indoor air quality (Fang *et al.*, 1996; Berglund, 1998) will, however, specify a narrower range for humidity. In the revision of 55-92 there is agreement to revert to the upper limit used in 1981, humidity ratio 12 g/kg, and no lower limit.

Long-term Evaluation of General Thermal Comfort Conditions

If criteria have to be met for 100% of the time of occupancy, also under extreme weather conditions, the heating and /or cooling capacity of any HVAC installation should be relatively high. Economic and/or environmental considerations may lead to allowing thermal conditions for a limited time to exceed the recommended ranges. By computer simulation, comfort conditions are often tested over longer periods of time, for different types of building and/or HVAC design. The need here is to give a number for the long-term comfort conditions for comparison of designs.

Today very little knowledge is available on the impact (reduction of energy use, smaller HVAC-systems, lost productivity, discomfort, economy) of allowing the space temperature to exceed recommended comfort limits. Several methods to sum up the length of time the comfort range is exceeded are recommended in ISO 7730rev. Some of the methods recommend differentially weighting the time outside the comfort zone, as a kind of degree-hour method.

The time during which the actual PMV exceeds the comfort boundaries is weighted with a factor which is a function of the PPD. Starting from a PMV-distribution on a yearly basis and the relation between PMV and PPD, the following is calculated:

Weighting factor $$wf = \frac{\mathrm{PPD}_{\text{actual PMV}}}{\mathrm{PPD}_{\text{PMV limit}}}$$

The weighting hours are totalled for a characteristic working period during 1 year.

Warm period: $\Sigma wf \times$ time hours, where PMV > $\mathrm{PMV}_{\text{limit}}$

Cold period: : $\Sigma wf \times$ time hours, where PMV < $\mathrm{PMV}_{\text{limit}}$

The summation of the product 'weighting factor × time' is called 'weighting time' in hours.

Table 3 illustrates this concept. The weighting factors are based on temperature difference wf (°C) and PPD; wf (PPD) is shown for a comfort range of 23–26°C, corresponding to sedentary work (1.2 met) and light summer clothing (0.5 clo). For temperatures above or below this interval, the number of hours will be multiplied with these factors. It will be seen that using the PPD weighting factor will result in a higher number of hours. The values may be used for the evaluation of long-term comfort conditions.

Table 3 Weighting factors based on temperature difference or PPD

Temperature °C		Weighting factors	
		wf(°C)	wf(PPD)
Cool	20	3	4,7
	21	2	3,1
	22	1	1,9
Neutral	23	0	0
	24	0	0
	25	0	0
	26	0	0
Warm	27	1	1,9
	28	2	3,1
	29	3	4,7

In a revision of international standards for the thermal environment, the procedure for making long-term evaluations must be carefully discussed. It seems inappropriate to use the same clothing level for the whole summer period May–September. It is important to study people's clothing behaviour before a method for long-term evaluation can be standardized (Morgan *et al.*, 2002).

INDOOR AIR QUALITY AND VENTILATION

For several years, ASHRAE has been working extensively on a revision of standard 62 for indoor air quality and ventilation. In the European standard organization, CEN, a working group under the technical committee TC156 'Ventilation for Buildings' has developed a technical report CR1752 'Ventilation for Buildings: Design Criteria for the Indoor Environment' (CR1752-1998).

In most standards and guidelines the indoor air quality is related to a required level of ventilation. This is somewhat different from the concept used for the thermal environment since it has not been possible to agree on a method for specifying the level of indoor air quality in a building. Instead, required ventilation rates are specified for different types of space and occupation.

In all of the standards more than one procedure is included. They all include a prescriptive method, where the minimum ventilation rates can be found in a table listing values for different types of space, as well as an analytical procedure for calculation of the required ventilation rate. By means of the analytical procedure the ventilation rates can be calculated on the basis of type of pollutant, emission rates and acceptable concentration. All of the proposed standards deal also with the health issue and not only the comfort issue.

Prescriptive Methods

The values in CR1752 are given for three classes where A corresponds to ~15% dissatisfied, B to ~20% and C to ~30%. The basis for the ventilation rates are given in Figure 4 from CR1752. The figure is based on studies by Berg-Munch *et al.* (1986) with Danish subjects, but similar results were found by Iwashita *et al.* (1990) with Japanese subjects and Cain *et al.* (1983) with North-American subjects.

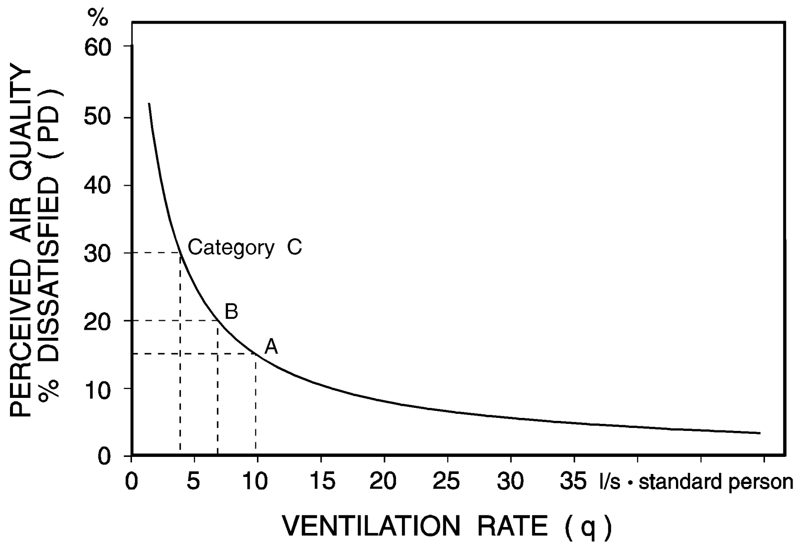

Figure 4 Dissatisfaction caused by a standard person (one olf) at different ventilation rates.

This corresponds then to the basic rates of 4 (Category C), 7 (Category B) and 10 l/s·standard person. In fact prEN13779 specifies different ways of expressing the quality of the indoor air, as shown in Table 4.

These classes do not, however, completely correspond to the three classes specified in CR1752, i.e. 4, 7 or 10 l/s/person.

Studies (Fanger *et al.*, 1988) have shown that pollution sources in buildings are coming from occupants, building materials, furnishing and the HVAC-system itself.

In CR1752 a required minimum ventilation rate is given per person and per square metre floor area, and the values are added. However, it is allowed only to design according to the ventilation rate per person, on the assumption that the building does not emit any pollution. Annex 1 shows the required ventilation rate for several types of space from CR1752.

Table 4 Classification of indoor air quality (IDA, prEN13779)

Category	Description	Classification parameters			
		CO_2 level ppm	Perceived air quality decipols	Classification by outdoor air per person $l\ s^{-1}\ person^{-1}$	
				Non-smoking	Smoking
IDA 1	High indoor air quality	≤ 400	< 1.0	>15	> 30
IDA 2	Medium indoor air quality	400 - 600	1.0 - 1.4	10 – 15	20 – 30
IDA 3	Acceptable indoor air quality	600 - 1000	1.4 – 2.5	6 – 10	12 – 20
IDA 4	Low indoor air quality	> 1000	< 2.5	<6	< 12

For the prescriptive method in the revision of ASHRAE 62rev, 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 the ventilation rate based on the person's activity and the floor area should take care of emissions from the building, furnishing, HVAC system etc.

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

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

where:

A_z = zone floor area: the net occupiable floor area of the zone m^2.

P_z = zone population: the largest number of people expected to occupy the zone during typical usage. *Note*: If P_z cannot be accurately predicted during design, it may be an estimated value based on the zone floor area and the default occupant density listed in Annex 2.

R_p = outdoor airflow rate required per person: these values are based on adapted occupants.

R_a = outdoor airflow rate required per unit area.

In a comparison of CR1752 and ASHRAE standard-62, the listed standards of the required ventilation rate for four different typical spaces are shown in Annex 2.

Carbon Dioxide and Human Bioeffluents

Humans produce carbon dioxide (CO_2) in proportion to their metabolic rate. By quantity it is the most important human bioeffluent. At the low concentrations typically occurring indoors, CO_2 is harmless and is not perceived by humans. Still it is a good indicator of the concentration of other human bioeffluents perceived as a nuisance. As an indicator of human bioeffluents, CO_2 has been applied quite successfully for more than a century. Figure 5 shows the percentage of dissatisfied visitors (un-adapted) as a function of the CO_2 concentration (above outdoors) for spaces where sedentary occupants are the exclusive pollution source. In lecture theatres, assembly halls and similar rooms with a high occupancy which may change in a short time, CO_2-monitoring is a well-established practice for controlling the supply of outdoor air. Although CO_2 is a good indicator of pollution caused by sedentary human beings, it is often a poor general indicator of perceived air quality. It does not acknowledge the many perceivable pollution sources not producing CO_2 and certainly not the non-perceivable hazardous air pollutants such as carbon monoxide and radon.

If sedentary occupants are assumed to be the only source of pollution, the CO_2 concentration above outdoors corresponding to the three categories will be A: 460 ppm, B: 660 ppm and C: 1190 ppm.

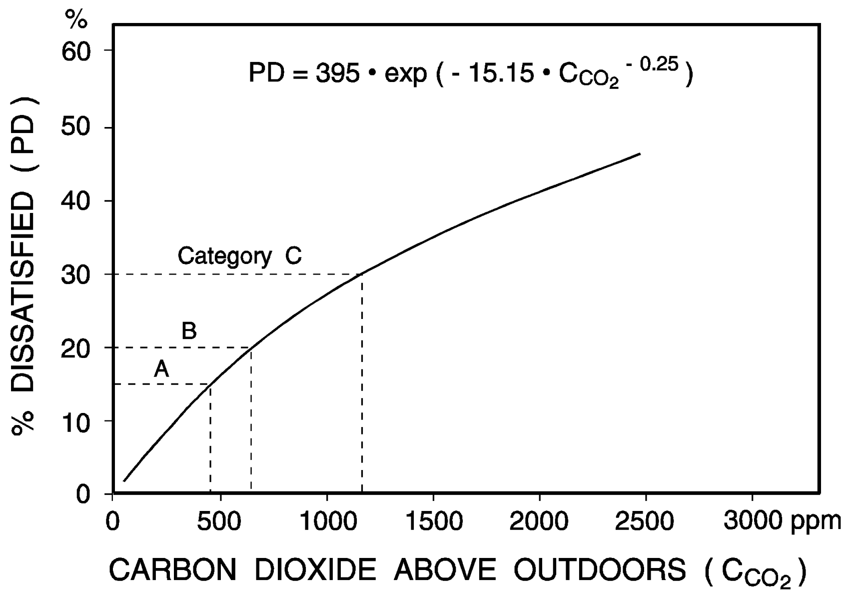

Figure 5 Carbon dioxide as an indicator of human bioeffluents. The curve shows the perceived air quality (% dissatisfied) as a function of the carbon dioxide concentration above outdoors. It applies to spaces where sedentary occupants are the exclusive pollution source. The concentration of carbon dioxide outdoors is typically around 700 mg/m^3 (350 ppm).

Analytical Procedure

All of the listed standards have also an analytical procedure, either in the standard text or in an informative appendix. In this procedure the required ventilation rate is calculated on a comfort basis (perceived odour and/or irritation) as well as on a health basis. The highest calculated value, which in most cases will be the comfort value, is then used as the required minimum ventilation rate. The basis for the calculation is in all standards based on a mass balance calculation.

The required ventilation rate (in l/s) is calculated as:

$$Q = \frac{G}{(C_i - C_o) \cdot E_v}$$

where:

G = total emission rate (mg/s);
C_i = concentration limit (mg/l);
C_o = concentration in outside air (mg/l)
E_v = ventilation effectiveness.

In all of the standards, however, knowledge concerning emission rates (G) and concentration limits (C_i) from a health point of view, is very limited. Within the next few years, knowledge will increase and data will be available from ongoing research projects and from testing by manufacturers of building materials and furnishing.

In ASHRAE 62-2001 rev, it is not specified on what basis the comfort ventilation should be calculated. Air cleaning may be taken into account in the analytical procedure. The concept of being able to design for different levels of indoor air quality has been included in a Scandinavian guideline (SCANVAC, 1991), in a Finnish guideline (FiSIAQ, 1995) and in DIN 1946.

Smoking

In all standards except the ASHRAE standard 62-89, for the basic ventilation rate it is assumed that no smoking takes place. When smoking does occur, an additional amount of outside air must be used in order to obtain an acceptable perceived air quality. An addendum to ASHRAE Standard 62.1 has, however, removed the sentence 'a moderate amount of smoking is included in the required ventilation rates in the prescriptive table'. In another addendum ASHRAE 62.o, a method for calculating the additional amount of ventilation needed to obtain acceptable perceived air quality is given. It is based on the values in Table 5.

Table 5 Required ventilation per cigarette

	Un-adapted (m^3/cig)	Adapted (m^3/cig)
Non-smokers	160	110
Smokers	40	30

The values for ASHRAE 62 are calculated based on a given amount of air per cigarette (Table 5), a normal smoking rate of 0.6–2.0 cigarettes per hour, and 3 cigarettes per hour in smoking lounges (100% smoking). In the USA, the average percentage of smokers is approximately 25% and a smoking rate of 1.1 cigarettes per hour. In many buildings in the USA smoking is, however, often allowed only in dedicated spaces. Based on ASHRAE 62-addendum o, Table 6 shows the required additional and total ventilation rate for various smoking-permitted areas. To obtain the total ventilation rate 8–10 l/s/person is added. By calculation of the extra ventilation rate the difference between adapted and un-adapted persons (Table 5) is taken into account, but for the base ventilation rate (8–10 l/s/person) this difference is not taken into account.

Table 6 Sample calculations using equation method for determining recommended extra outdoor ventilation rates in smoking-permitted areas in various facilities (ASHRAE-add. 62.o)

	Proportion of smokers SM	Smoking rate SR	Outdoor air requirements			
			Extra ventilation rate		Total ventilation rate	
		Cigarette/ Smoker/h	L/s/person (un-adapted)	L/s/person (adapted)	L/s/person (un-adapted)	L/s/person (adapted)
Smoking lounge	1	3	–	25	–	33
Heavy smoking lounge	1	6	–	50	–	58
Bar, cocktail lounge	0.25	1	9	6	19	16
Heavy smoking bar, cocktail lounge	0.5	2	–	9	–	29
Dining room 1	0.2	0.6	5	3	15	13
Gambling casino 2	0.2	1.5	11	8	21	18
Conference room	0.2	1.1	8	6	16	14
Office	0.2	0.6	5	3	15	13

The required additional amount of ventilation air per person, when smoking takes place, is shown in Annex 1 for the CR 1752.

If it is assumed that people are the only source (bioeffluents, smoking), CR1752 gives specific rates in Table 7.

Table 7 Required ventilation per person with and without smoking

Standard	Class	Required ventilation l/s/person			
		Non-smoker	20% smoker	40% smoker	100% smoker
	A	10	20	30	30
CR1752	B	7	14	21	21
	C	4	8	12	12

DISCUSSION AND CONCLUSIONS

Standards for the thermal environment are fairly well established and relatively consistent with each other (ASHRAE-55, ISO7730). Fulfilling the given criteria does not, however, mean 100% acceptance. Due to individual differences it may be very difficult to satisfy everybody in a space. Individual control of the thermal environment or individual adaptation (clothing, activity) will, however, increase the level of acceptance.

In the above criteria, there are some restrictive requirements to the air velocity due to the sensation of draught. In warm environments it may be beneficial for the total comfort to increase the air velocity above these levels. This effect is partly included in the use of the PMV index. Both, ASHRAE and ISO, accept an increased air velocity up to 0.8 m/s (sedentary), but the increased air velocity must be under individual control.

Field studies have shown that for heated and air-conditioned buildings the use of the PMV-PPD index agrees with the results. But for ‘free running’ buildings in warm climates, where it is necessary in summer to rely on natural ventilation by opening windows or using fans, there seems to be an additional adaptation that cannot be explained solely by the adaptation of clothing. It may be due partly to adaptation of activity, which is very difficult to measure in the field, and partly to another level of expectation.

A further issue is whether it should be allowed for certain periods of time to accept conditions outside the specified criteria or whether the thermal environment 100% of the time must be within the given range. For each of the thermal comfort factors it may be possible from measurements or calculations to reckon with a factor ‘%-dissatisfied × time’ to take into account the length of time and the degree by which the conditions deviate from the established comfort criteria. For such factor(s), additional criteria may be established or the values could be given as a measure of environmental quality.

A comparison between the required levels of ventilation rate in ASHRAE 62 and in CR1752 has been presented. Both standards include a prescriptive procedure, where the required minimum ventilation rate is listed in tables with values for different types of space.

Both standards include also an analytical method, where the required ventilation rate is calculated on the basis of comfort and health criteria. There is, however very little information on acceptable comfort and/or health criteria in the standards. Furthermore, there is a lack of information on emission rates from materials and other sources. This makes it very difficult today to use the analytical methods.

CR1752 includes the possibility of designing for different levels of perceived air quality, while ASHRaE-62.1 is a minimum standard. Therefore ASHRAE 62.1 is based on satisfying adapted persons, i.e., people who are occupying a space and have adapted to the odour level, while CR 1752 is based on un-adapted, i.e., people entering a space. The basic for the ventilation rates has been mainly studied with Scandinavian or North-American subjects. The basic ventilation rates for body odour have, however, been validated with Japanese subjects. Both documents recognise pollution source from people and their activity, building incl. furnishing and the HVAC-system itself. There is, however, a lack of data for the building and HVAC-system component not only for Asian buildings, but in general.

Except for the technical report CR1752, separate standards exist for thermal comfort and indoor air quality. As both factors are important for comfort, health and performance of the occupants, and are also necessary for the design of buildings and HVAC systems, it may be beneficial to combine the standards.

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Annex 1 Recommended criteria for thermal comfort and ventilation rates according to CR 1752 (1998) and ISO EN 7730rev. (2003)

Type of building /space	Activity met	Occupancy (person/m^2)	Category	Operative temperature (°C)		Maximum mean air velocity (m/s)		Ventilation (l/s/m^2)	
				Summer (cooling season)	Winter (heating season)	Summer (cooling season)	Winter (heating season)	Basic	Add. by smo-king
Single office	1.2	0.1	A	24.5±1.0	22.0±1.0	0.18	0.15	2.0	–
			B	24.5±1.5	22.0±2.0	0.22	0.18	1.4	–
			C	24.5±2.5	22.0±3.0	0.25	0.21	0.8	–
Landscaped office	1.2	0.07	A	24.5±1.0	22.0±1.0	0.18	0.15	1.7	0.7
			B	24.5±1.5	22.0±2.0	0.22	0.18	1.2	0.5
			C	24.5±2.5	22.0±3.0	0.25	0.21	0.7	0.3
Conference Room	1.2	0.5	A	24.5±1.0	22.0±1.0	0.18	0.15	6.0	5.0
			B	24.5±1.5	22.0±2.0	0.22	0.18	4.2	3.6
			C	24.5±2.5	22.0±3.0	0.25	0.21	2.4	2.0
Auditorium	1.2	1.5	A	24.5±1.0	22.0±1.0	0.18	0.15	16[a]	–
			B	24.5±1.5	22.0±2.0	0.22	0.18	11.2	–
			C	24.5±2.5	22.0±3.0	0.25	0.21	6.4	–
Cafeteria/ restaurant	1.2	0.7	A	24.5±1.0	22.0±1.0	0.18	0.15	8.0	–
			B	24.5±2.0	22.0±2.5	0.22	0.18	5.6	5.0
			C	24.5±2.5	22.0±3.5	0.25	0.21	3.2	2.8
Classroom	1.2	0.5	A	24.5±0.5	22.0±1.0	0.18	0.15	6.0	–
			B	24.5±1.5	22.0±2.0	0.22	0.18	4.2	–
			C	24.5±2.5	22.0±3.0	0.25	0.21	2.4	–
Kindergar-Ten	1.4	0.5	A	23.5±1.0	20.0±1.0	0.16	0.13	7.1	–
			B	23.5±2.0	20.0±2.5	0.20	0.16	4.9	–
			C	23.5±2.5	20.0±3.5	0.24	0.19	2.8	–
Depart-ment store	1.6	0.15	A	23.0±1.0	19.0±1.5	0.16	0.13	4.2	–
			B	23.0±2.0	19.0±3.0	0.20	0.15	3.0	–
			C	23.0±3.0	19.0±4.0	0.23	0.18	1.6	–

[a]It may be difficult to meet the Category A draught criteria.
[b]Additional ventilation required for comfort when 20% of the occupants are smokers. The health risk of passive smoking should be considered separately.

Annex 2: Recommended criteria for ventilation rates in smoking free spaces according to ASHRAE 62.1rev. (2003) and CR 1752 (1008)

Type of building/ Space	Occupancy (person/m^2)	Category CEN	Minimum ventilation rate, i.e. for occupants only (l/s/person)		Additional ventilation for building (add only one) (l/s/m^2)			Total (l/s/m^2)	
			ASHRAE R_p	CEN	CEN low-polluting building[a]	CEN *not* low-polluting building	ASHRAE R_a	CEN Low Pol.	ASHRAE
Single office (cellular office)	0.1	A	2.5	10	1.0	2.0	0.3	2	0.55
		B		7	0.7	1.4		1.4	
		C		4	0.4	0.8		0.8	
Landscaped office	0.07	A	2.5	10	1.0	2.0	0.3	1.7	0.48
		B		7	0.7	1.4		1.2	
		C		4	0.4	0.8		0.7	
Conference room	0.5	A	2.5	10	1.0	2.0	0.3	6	1.55
		B		7	0.7	1.4		4.2	
		C		4	0.4	0.8		2.4	
Auditorium	1.5	A	3.8	10	1.0	2.0	0.3	16	6
		B		7	0.7	1.4		11.2	
		C		4	0.4	0.8		6.4	
Cafeteria/ restaurant	0.7	A	3.8	10	1.0	2.0	0.9	8	1.17
		B		7	0.7	1.4		5.6	
		C		4	0.4	0.8		3.2	
Classroom	0.5	A	3.8	10	1.0	2.0	0.3	6	2.2
		B		7	0.7	1.4		4.2	
		C		4	0.4	0.8		2.4	
Kinder-garten	0.5	A	5.0	12	1.0	2.0	0.9	7	3.4
		B		8.4	0.7	1.4		4.9	
		C		4.8	0.4	0.8		2.8	
Department store	0.15	A	3.8	14.7	2.0	3.0	0.6	4.1	1.17
		B		10	1.4	2.1		2.9	
		C		6	0.8	1.2		1.7	