BRITISH STANDARD

BS EN 4618:2009

Aerospace series — Aircraft internal air quality standards, criteria and determination methods

ICS 49.095

BSI
British Standards

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Luft- und Raumfahrt - Qualitätsstandards für Kabinenluft, Kriterien und Messverfahren

This European Standard was approved by CEN on 8 August 2009.

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Foreword

This document (EN 4618:2009) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2010, and conflicting national standards shall be withdrawn at the latest by March 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard has been prepared in order to specify requirements and determination methods for newly certificated commercial passenger aircraft programmes. It may also apply to current production aircraft, should it be shown to be technically feasible and economically justifiable. The standard distinguishes between safety, health and comfort conditions for passengers and crew under a variety of phases of flight, including embarkation and disembarkation.

The standard is intended for use in design, manufacturing, maintenance and normal operation of commercial aircraft. The standard committee has tried to make the standard performance based. This means that only parameters of direct effect on safety, health and comfort of aircraft occupants are considered. Prescriptive design solutions, such as ventilation flow rates, are not described in the clauses of the standard. Nevertheless, in exceptional cases, current technology is used in notes, appendices and/or recommendations to describe available solutions that may meet the objectives of individual requirements of the standard.

Regulatory bodies may apply this standard or parts thereof.

1 Scope

This standard specifies requirements and determination methods for newly certificated commercial passenger aircraft programmes.

This standard applies to newly certificated commercial passenger aircraft programmes. It may also apply to current production aircraft if it does not carry significant penalties, i.e. if it can be shown to be technically feasible and economically justifiable.

This standard covers the period from first crew embarkation to last crew disembarkation.

NOTE 1 During embarkation and disembarkation, reduced temperatures in the cabin may be desirable due to increased metabolic activity of the occupants. In some ground cases, the aircraft environmental control system (ECS) may not be able to compensate for the external conditions influencing the cabin comfort conditions, such as open doors, extreme hot/cold ground/air temperatures or radiant heat. In this case, external air-conditioning systems, for example conditioned low-pressure ground air or high-pressure supply, may be used to supplement the aircraft ECS. If the temperature range stated in this standard is regularly exceeded (either above or below the stated range), changes to airline and/or airport procedures and/or aircraft design should be introduced.

NOTE 2 During ground operations, the external air quality may adversely influence the air quality within the aircraft cabin. Contamination produced as a result of servicing activities or ground operations vehicles may enter the aircraft directly, for example via open doors, and the ECS may not be able to effectively control contaminant levels in the cabin. Airline and airport operational procedures should be organised so as to avoid direct contamination of the cabin from these pollutant sources. If the contaminant ranges stated in this standard are regularly exceeded, changes to airline and/or airport procedures and/or aircraft design should be introduced.

Outside air quality levels would usually be regulated by national authorities.

The population under consideration – passengers and crew – excludes individuals with pre-existing infirmity or ill health conditions.

All values given in this document are sea-level equivalent (see Clause 4). According to the Air Quality Guidelines WHO 1999, paragraph 2.2.3, ‘For gaseous pollutants, no increase in effects over those experienced at sea level would be expected as a result of the increase of the inhalation, as the partial pressures of the pollutant gases will fall in line with that of oxygen.’ The limit concentrations at flight altitude can therefore be defined using pressure ratios.

Annex A provides the formula for calculating allowable concentrations at flight altitude.

There are many potential sources of contamination, which could affect the aircraft cabin environment. It would be impractical to set limits for all the chemical constituents of these sources.

The presence of marker compounds in concentrations that exceed the cabin air quality comfort, health or safety limits set in the standard may indicate that maintenance, procedural or operational change or design change is required to bring the air quality back within the limits set in this standard.

Several sources have been considered to identify contaminants produced during normal operation. The possible sources have been analysed to identify which chemical groupings are related to each one. At least one compound from each grouping identified for each potential source has been chosen as representative of that source.

To define the performance of the ECS, maximum contamination limits are given for the selected marker compounds. The marker compounds have been selected to be:

— Measurable;

— Representative of contaminants produced during operation;

— Balanced across the chemical groupings of the potential contamination sources.

The selected marker compounds may occur in several of the selected potential sources. A full list of all compounds considered is given for completeness. Some of the compounds were subsequently disregarded because they were:

— Expected to appear only in very low concentrations, and/or

— Have low toxicity for given TLVs, and/or

— Below the quantification limit of measurement method.

Where this is the case is marked in Table 1. Additionally, while some compounds may be present in many of the identified potential sources, they are only relevant (under the guidelines given above) for some of the potential sources. In this case this is also marked in Table 1.

The potential sources under consideration are described below:

— Bio-effluents – compounds produced by the occupants;

— Cabin Interior – compounds that may be used during cabin servicing and cleaning;

— Solvents – compounds that may be present in the cabin due to, for example, cabin furnishing off-gassing;

— External Conditions – compounds likely to be present in the environment, specifically near the airport, either from natural or man made sources;

— Exhaust – compounds likely to be present in the engine or APU exhaust, which under certain environmental conditions may be ingested into the outside air intake;

— Oils, lubricants and hydraulic fluids – compounds present in these fluids, and/or their thermal breakdown products, that may enter the cabin under certain conditions;

— Fuel – compounds present in fuels that may enter the cabin under certain conditions.

Contaminants indicative of engine/APU lubricant or fuel leaks would enter the cabin through the bleed air system. The bleed air system may also carry ingested exhaust fumes, hydraulic fluid leaks and environmental pollution in to the cabin. On the ground, exhaust fumes and environmental pollution may also enter through open aircraft doors.

Table 1 — Marker compounds and their potential sources in the cabin

Category	Group	Compound	CAS No.	Bio-effluents	Cabin Interior	Solvents	External Conditions	Exhaust	Oils, Lubricants & Hydraulics	Fuel
Inorganic Compounds		Carbon Dioxide	124-38-9	☒			☒ [a]	☒ [a]		
		Carbon Monoxide [a]	630-08-0				☒	☒	☒	
		Nitrogen Oxides [b]	10102-44-0				☒	☒		
		Ozone [a]	10028-15-6				☒			
Inorganic / Organic Particles		Particles, aerosols		☒ [a]	☒ [a, c]		☒	☒	☒	☒
		Micro-organisms		☒ [a]	☒ [a]		☒			
		Endotoxins		☒ [a]	☒ [a]		☒			
Aliphatic Compounds	Alkanes	Methane [b]	74-82-8	☒				☒		☒
	Ketones	Acetone [a]	67-64-1	[d]		☒			☒	
		Methyl Ethyl Ketone [a]	78-93-3			☒			☒	
	Aldehydes	Acetaldehyde [a]	75-07-0					☒	☒	☒
		Acrolein [a]	107-02-8					☒	☒	☒
		Formaldehyde [a]	50-00-0		☒ [e]	☒		☒	☒	☒
	Halogen Derivatives	Methylene Chloride [a]	74-87-3			☒			☒	

continued

Table 1 — Marker compounds and their potential sources in the cabin *(concluded)*

Category	Group	Compound	CAS No.	Bio-effluents	Cabin Interior	Solvents	External Conditions	Exhaust	Oils, Lubricants & Hydraulics	Fuel
Aromatic Compounds		Benzene [a]	71-43-2					☒		☒
		Tricresyl Phosphate [b]	1330-78-5						☒	
		Toluene	108-88-3			☒ [a]		☒	☒	☒
Polycyclic Aromatic Hydrocarbons		Benzo (alpha) Pyrene [b]	50-32-8					☒		☒
		Naphthalene [b]	91-20-3					☒	☒	☒

[a] Identified compound linked to source as marker compound (measured), this may include aerosols, vapour phase and thermal decomposition products.

[b] Identified compound linked to source but not as marker compound (no measurement), this may include aerosols, vapour phase and thermal decomposition products.

[c] If ozone is present in the cabin it may react with plastics in the cabin to form particles; Reference: CONCISE INTERNATIONAL CHEMICAL ASSESSMENT DOCUMENT N° 5.

[d] Acetone is normally produced only in very minor quantities by the human body. Some health problems do lead to significant synthesis of acetone, however this is not considered by this standard (reference to be provided).

[e] If ozone is present in the cabin it may react with plastics in the cabin to synthesise formaldehyde; Reference: CONCISE INTERNATIONAL CHEMICAL ASSESSMENT DOCUMENT N° 5.

Criteria relative to environmental criteria concern:

— thermal comfort;

— pressure rate of change;

— cost of compliance.

Changes in costs related to the need to comply with a new standard may arise from the following factors:

— expenditure on R&D for the development of new technologies;

— non recurring costs for the development of new products;

— recurring costs in the production of new products;

— certification and compliance testing;

— operating costs for new products;

— the residual value of the current fleet.

However, for this proposed standard the programme of measurements in the sky carried out in the EC CabinAir project demonstrated that the values chosen for pollutants and comfort criteria can generally be met by technology currently available. As a result, the only increases in costs are likely to be associated with a limited extension of the certification process and possibly with through-life compliance testing. In both of these cases the overall impact on total costs is expected, at most, to be very much at the marginal level.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 481, *Workplace atmospheres — Size fraction definitions for measurement of airborne particles.*

EN 14181:2004, *Stationary source emissions — Quality assurance of automated measuring systems.*

EN ISO 7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria (ISO 7730:2005).*

EN ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling (ISO 16017-1:2000).*

ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*.

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method.*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID.*

FAR 25, *Airworthiness standards — Transport category airplanes.*

JAR 25, *Large aeroplanes.*

ASTM D6399-04, *Standard Guide for Selecting Instruments and Methods for Measuring Air Quality In Aircraft Cabins.* 1)

ASTM D6699, *Standard Practice for Sampling Liquids Using Bailers.* 1)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
safety limits
limits for cabin environment parameters that if exceeded would prevent the safe operation of the aircraft

NOTE Where appropriate, limits such as occupational exposure limits and regulatory limits are taken from cognizant authorities.

3.2
health limits
limits for cabin environment parameters that if exceeded would lead to temporary or permanent pathological effects to the occupants

NOTE Where appropriate, limits such as occupational exposure limits and regulatory limits are taken from cognizant authorities.

3.3
comfort limits
limits for cabin environment parameters that if exceeded would not achieve an acceptable cabin environment

NOTE An acceptable cabin environment is defined as one in which a substantial majority of the people exposed would not be expected to express dissatisfaction with the air quality contaminants and/or environmental criteria. Where appropriate, comfort limits are drawn from cognizant authorities that provide indoor environment standards and guidelines.

4 Air quality

4.1 General

All standards and guidelines referenced in this document must be referred to directly to confirm the correct interpretation and applicability.

For the purpose of this standard, the sea-level equivalent reference conditions are 101,3 kPa and 20 °C. This choice is based on the European guidelines for threshold values definition for contaminants in spaces with human occupancy. It should be noted that the ICAO standard conditions are 101,3 kPa and 15 °C, and that current FAR/JAR use 101,3 kPa and 25 °C as reference conditions.

NOTE For any given contaminant and class (Safety, Health or Comfort), where there exist two or more exposure limits defined by cognizant authorities, the most conservative value has been retained.

1) This standard is published by: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

4.2 Carbon dioxide

4.2.1 General

Carbon dioxide is present at low levels in ambient air and is a normal product of human respiration. A further source can be found in the use of dry ice to preserve food and drink supplies.

4.2.2 Requirements and rationale

	Limits	Rationale
Safety	9 130 $mg.m^{-3}$ (5 000 ppmv)	1
Health	36 520 $mg.m^{-3}$ (20 000 ppmv) (15 min exposure)	2
Comfort	3 650 $mg.m^{-3}$ (2 000 ppmv)	3

Rationale:

1 No cumulative effect to be expected for breathing carbon dioxide but only acute effects.

Although there is evidence that concentrations approaching 20 000 ppmv will cause no symptoms, in the light of the relative ease in maintaining compliance with a 5 000 ppmv maximum limit, it is considered reasonable to retain the lower value, as currently set by FAR/JAR 25.

2 Extracted from the EU TLV, see 'Technical rules for hazardous substances (TRGS) 402 and 900, Germany'.

Extracted from the short time exposure factor that is equal to 4 for carbon dioxide in EU rules.

3 Although carbon dioxide concentration may be used as a 'Comfort Surrogate', it is only one such parameter (others may include temperature, humidity and pressure). Current FAR regulations specify 0,55 lb/mn/pers (equivalent to 0,004 2 kg/s/pers and a flow rate at sea level of 3,4 l/s/pers or 7,2 cfm at sea level). This corresponds to a steady state metabolic carbon dioxide level of about 1 850 ppmv (assuming an ambient carbon dioxide level of 350 ppmv). In the absence of specific bio-effluents control measures, an outside air ventilation rate of 5 cfm per person is normally recognised for bio-effluents control for satisfying greater than 80 % of occupants (Ref ASHRAE 62 N). This corresponds to a carbon dioxide level of 2 500 ppmv, in an occupied pressurised aircraft cabin. In this specific instance for aircraft cabin environment, it is assumed that the carbon dioxide emission is solely due to metabolic activity, and that the ambient carbon dioxide concentration is 350 ppmv. If, on the other hand, specific bio-effluent reduction measures are available, carbon dioxide concentration should not be considered as a comfort surrogate, but solely under health and safety considerations as defined in rationales 1 and 2.

For flight conditions, the CabinAir flight measurement programme has consistently indicated an absolute carbon dioxide level below 2 000 ppmv. The results of the analysis of the data collected with the subjective comfort questionnaire further demonstrate that carbon dioxide levels do not affect comfort.

A comfort limit of 2 000 ppmv has thus been chosen.

Reduced ventilation rate for passengers can be considered provided that it can be demonstrated that the air-quality is equivalent to a currently ventilated compartment.

4.2.3 Measurement method

CAS-No. 124-38-9

Measurement: Non-dispersive infrared adsorption.

Quantification limit: ≤ 2 % related to upper limit of measurement.

Accuracy: $\leq \pm 2$ % related to upper limit of measurement.

Reference: EN 14181:2004, *Stationary source emissions — Quality assurance of automated measuring systems* .

4.3 Carbon monoxide

4.3.1 General

Carbon monoxide results from incomplete combustion of carbon compounds. Under certain ground conditions, such as proximity to servicing vehicles and/or other aircraft with engines/APU running or using the APU with a tailwind, ingestion by the engines or APU of exhaust gases (which may contain carbon monoxide) can occur. Carbon monoxide may enter the cabin as a thermal decomposition products ingested into the engine bleed air from synthetic oil or hydraulic fluid.

Due to its insidious nature (odourless with symptoms of drowsiness leading to death) carbon monoxide is referenced in the FAR and JAR 25.

4.3.2 Requirements and rationale

	Limits	Rationale
Safety	58,1 $mg.m^{-3}$ (50 ppmv) peak value (JAR, FAR)	1
Health	29,1 $mg.m^{-3}$ (25 ppmv) TWA 1 h (WHO/LQL) 11,6 $mg.m^{-3}$ (10 ppmv) TWA 8 h (WHO/LQL)	2
Comfort	–	3

Rationale:

1 Regulatory safety JAR

Although there are data available regarding human performance degradation, the additive effects of altitude have not been fully researched, particularly in respect to factors such as exposure over several hours and exercise. However, except during a contaminated air event resulting due to a system failure, malfunction or contamination, the known sources of carbon monoxide in aircraft operations are limited to the ground phase.

Although concentrations of up to around 100 ppmv would be expected to induce no symptoms, the ease by which compliance to a lower limit can be achieved, combined with the incompleteness of research, has led to the conclusion that the current regulatory limit of 50 ppmv (JAR and FAR 25) should be retained in this standard.

2 World Health Organisation Guidelines for Air Quality, Geneva, 2 000 limits are set in order to not exceed the 2,5 % for carboxyhaemoglobin level.

3 Comfort limits are not defined because within the health limits there are no effects on comfort.

4.3.3 Measurement method

Same as for carbon dioxide.

4.4 Ozone

4.4.1 General

Ozone occurs at high concentration in the upper troposphere/lower stratosphere, at concentrations that can affect the health of crew and passengers. For this reason, the FAR and JAR have introduced regulations to limit the amount of ozone in the cabin. These regulations have traditionally been fulfilled either through operational measures or by installing ozone conversion equipment on the aircraft.

4.4.2 Requirements and rationale

	Limits	**Rationale**
Safety	—	1
Health	0,50 $mg.m^{-3}$ (0,25 ppmv), peak value (FARs) 0,20 $mg.m^{-3}$ (0,1 ppmv) TWA 3 h (FARs) TWA 8 h < 0,12 $mg.m^{-3}$ (0,06 ppmv) (WHO guidelines/ EC directive)	2
Comfort	—	3

Rationale:

1 —

2 FAR 25.832 determines ozone concentrations for different flight levels: not to exceed **0,25 ppmv**, sea level equivalent, at any time **above 32 000 feet altitude (9 800 m)**.

0,1 ppmv, time-weighed average during any 3-hr interval **above 27 000 feet altitude (8 200 m)**.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.4.3 Measurement method

Measurements should be taken in the cabin and not in incoming air.

Analytical methods are also available to calculate the ozone concentration in the cabin (see AC120/38- FAR document).

Take information about measurement facility

CAS-No. 10028-15-6

Method:

— Measurement: Chemiluminescence method;

— Quantification limit: 0,001 5 ml/m^3;

— Accuracy: ± 20 % related to upper limit of measurement.

Reference: VDI (Association of Engineers, Germany), clean air guideline No. 2468 (1978)

Method:

— Sampling: Impinger containing Indigocarmin;

— Measurement: VIS- Spectrometer (623 nm);

— Quantification limit: 0,011 mg/m^3 (sampling volume: 80 l);

— Accuracy: ± 21 %.

Reference: DFG (German Research Foundation) (1998)

4.5 Ultrafine particles

No criteria exist at present for ultrafine particles. However, typical values found in the cabin of a taxiing aircraft are 100 000-300 000 particles/cm^3. In general, levels less than 500 particles/cm^3 have been measured during cruise. Peaks of ultrafine particles in the cabin have been associated with taxiing, galley usage and food preparation.

4.6 $PM_{2,5}$

4.6.1 Requirements and rationale

	Limits	Rationale
Safety	—	1
Health	100 µg.m^{-3} (TWA 1 h) 40 µg.m^{-3} (continuous)	2
Comfort	—	3

Rationale:

1 There is no evidence to suggest that particulate matter up to a size of 2,5 µm constitutes a safety issue.

2 Health Canada – Exposure guidelines for residential air quality, 1995.

High levels of particles may be linked to respiratory difficulties. On non-smoking flights, occupants and food are the main emitters of particles in the cabin during flight.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.6.2 Measurement method

ASTM D6699

4.7 PM_{10}

4.7.1 Requirements and rationale

	Limits	Rationale
Safety	—	1
Health	150 µg.m^{-3} (TWA 24 h)	2
Comfort	—	3

Rationale:

1 There is no evidence to suggest that particulate matter up to a size of 10 µm constitutes a safety issue.

2 American Society of Heating, Refrigerating and Air-Conditioning Engineers – Ventilation for acceptable air quality, ANSI/ASHRAE 62-1999.

High levels of particles may be linked to respiratory difficulties. On non-smoking flights, occupants and food are the main emitters of particles in the cabin during flight.

For ground conditions (doors opened and/or ECS AC packs off), the level of particles in the cabin may be affected by external conditions. Outside air contamination levels would usually be regulated by national authorities.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.7.2 Measurement Method

ASTM D6399–04

Method:

— Sampler: Cyclone + Filter;

— Measurement: Gravimetric (Filter weight);

— Quantification limit: 0,5 mg/m^3 (sampling volume: 200 l);

— Accuracy: Depends on dust size distributions.

Reference: NIOSH, No. 0600 (1994)

Method:

— Sampler: BIA-Dustsampler (according to EN 481 – size fraction definitions) + Filter;

— Measurement: Gravimetric (filter weight);

— Quantification limit: 0,3 mg/m^3 (900 l);

— Accuracy: Depends on dust size distributions.

Reference: BIA (Institute for Occupational Safety, Germany), No.6068 (2003)

4.8 Acetone (Propanone)

4.8.1 General

In this standard, acetone is used as a tracer compound for solvents. Small quantities of acetone may be present in the cabin due to off-gassing.

4.8.2 Requirements and rationale

	Limits	Rationale
Safety	3 630 $mg.m^{-3}$ (1 500 ppmv) (15 min exposure) 1 210 $mg.m^{-3}$ (500 ppmv) (TWA 8 h)	1
Health	1 188 $mg.m^{-3}$ (500 ppmv) (TWA 8 h) 1 782 $mg.m^{-3}$ (750 ppmv) (STEL 15')	2
Comfort	240 $mg.m^{-3}$ (99 ppmv)	3

Rationale:

1 UK short-term exposure limit (15 min reference period) and long-term exposure limit (8 hr reference period).

2 AGCIH TLVs 2001, Guide to occupational exposure values.

No WHO guideline for acceptable concentration for general population for protection against health effects.

3 Odour threshold reported in Guidelines for Air Quality, WHO, Geneva, 2000.

4.8.3 Measurement methods

CAS-No 67-64-1

Method:

— Sampling: Solid sorbent tube (charcoal);

— Desorption: Carbon disulfide;

— Measurement: GC/FID;

— Quantification limit: 100 mg/m^3 (sampling volume: 0,5 l);

— Accuracy: ± 8,2 %.

Reference: NIOSH, No. 1300 (1994)

Method:

— Sampling: Solid sorbent tube (charcoal);

— Desorption: Carbon disulfide;

— Measurement: GC/FID;

— Quantification limit: 0,5 mg/m^3 (sampling volume: 40 l);

— Accuracy: ± 8,8 %.

Reference: BIA (Institute for Occupational Safety, Germany) No. 6032 (1991)

4.9 Methyl Ethyl Ketone (Butanone)

4.9.1 General

In this standard, butanone is used as a tracer compound for solvents and fuel. Small quantities of butanone may be present in the cabin due to off-gassing. Under normal in-flight operating conditions, only trace amounts of fuel products are present in the bleed air supply. Under certain ground conditions, such as proximity to other aircraft with engines/APU running or using the APU with a tailwind, ingestion by the engines or APU of fuel vapours can occur.

4.9.2 Requirements and rationale

	Limits	Rationale
Safety	897,8 mg.m^{-3} (300 ppmv) (15 min exposure) 1 795,5 mg.m^{-3} (600 ppmv) (TWA 8 h)	1
Health	598,5 mg.m^{-3} (200 ppmv) (TWA, 8 h) 897,8 mg.m^{-3} (300 ppmv) (STEL 15')	2
Comfort	—	3

Rationale:

1 UK short-term exposure limit (15 min reference period) and long-term exposure limit (8 hr reference period).

2 ACGIH TLVs 2001, Guide to occupational exposure values.ACGIH was chosen to be used for health as it is more conservative than the UK exposure limits

3 Comfort limits cannot be defined. Comfort is covered by the health limit.

4.9.3 Measurement methods

CAS-No. 78-93-3

Method:

— Sampling: Solid sorbent tube (coconut shell charcoal);

— Desorption: Carbon disulfide;

— Measurement: GC/FID;

— Quantification limit: 50 mg/m^3 (sampling volume: 3 l);

— Accuracy: ± 17,8 %.

Reference: NIOSH, No. 2500 (1994)

Method:

— Sampling: Solid sorbent tube (silicagel);

— Desorption: Diethyl ether;

— Measurement: GC/FID;

— Quantifiaction limit: 1,7 mg/m^3 (sampling volume: 10 l);

— Accuracy: ± 3,9 %.

Reference: BIA (Institute for Occupational Safety, Germany) No. 6395 (1993)

4.10 Acetaldehyde

4.10.1 General

In this standard, acetaldehyde is used as a tracer compound for engine lubricants and solvents. Under normal in-flight operating conditions, only trace amounts of engine lubricants are present in the bleed air supply. Small quantities of acetaldehyde may be present in the cabin due to off-gassing.

4.10.2 Requirements and rationale

	Limits	Rationale
Safety	45 $mg.m^{-3}$ (25 ppmv), over 15 min	1
Health	1,8 $mg.m^{-3}$ (1 ppmv), for 24 h	2
Comfort	—	3

Rationale:

1 ACGIH STEL - ACGIH TLVs 2001, Guide to occupational exposure values. These limits are more strict than the UK limits used for Acetone and Methyl Ethyl Ketone.

2 WHO indicates 1 ppmv over 24 h.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.10.3 Measurement method

CAS-No 75-07-0:

Method:

— Sampling: Midget bubbler containing Girard T solution;

— Measurement: HPLC, UV detector, 245 nm;

— Quantification limit: 18 ml/m^3 (sampling volume: 60 l);

— Accuracy: ± 14,4 %.

Reference: NIOSH, No. 3507 (1994)

Method:

— Sampling: Solid sorbent tube (2,4- Dinitrophenylhydrazone on silicagel);

— Desorption: Acetonitrile;

— Measurement: HPLC, UV detector, 365 nm;

— Quantification limit: 4 µg/m^3 (sampling volume: 6 l);

— Accuracy: ± 11,9 %.

Reference: DFG (German Research Foundation) (1996)

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method.*

4.11 Acrolein

4.11.1 General

Acrolein is being used in this standard as a tracer compound for lubricants and hydraulic fluids.

4.11.2 Requirements and rationale

	Limits	Rationale
Safety	0,75 mg.m^{-3} (0,3 ppmv), 15 min 0,25 mg.m^{-3} (0,1 ppmv), TWA 8 h	1
Health	0,05 mg.m^{-3} (0,02 ppmv), TWA 30 min	2
Comfort	—	3

Rationale:

1 OSHA – as the OSHA limits are set on the basis of acrolein being an eye and nose irritant, it is considered reasonable to use them as safety limits in this standard.

2 WHO Air quality Guidelines, Geneva 2000 – WHO 1992b, EHC 127.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.11.3 Measurement method

CAS-No. 107-02-8

Method:

— Sampling: Solid sorbent tube (2-(hydroxymethyl) piperidine on XAD-2);

— Desorption: Toluene;

— Measurement: GC/Nitrogenspecific detector;

— Quantification limit: 0,12 mg/m^3 (sampling volume: 24 l);

— Accuracy: ± 29 %.

Reference: NIOSH, No. 2501 (1994)

Method:

— Sampling: Solid sorbent tube (2,4-Dinitrophenylhydrazone on silicagel);

— Desorption: Acetonitrile;

— Measurement: HPLC, UV detector, 365 nm;

— Quantification limit: 0,02 mg/m^3 (sampling volume: 20 l);

— Accuracy: ± 11,5 %.

Reference: DFG (German Research Foundation) (1992)

4.12 Formaldehyde

4.12.1 General

Formaldehyde is a tracer compound for engine lubricants, solvents used in plastic manufacture and some cleaning agents. Small quantities of formaldehyde may be present in the cabin due to off-gassing, or due to cleaning usage (generally cleaning fluids containing formaldehyde are not permitted for use on aircraft).

4.12.2 Requirements and rationale

	Limits	Rationale
Safety	2,47 mg.m^{-3} (2 ppmv), 15 min 0,93 mg.m^{-3} (0,75 ppmv), TWA 8 h	1
Health	< 0,1 mg.m^{-3} (0,08 ppmv), 30 min exposure	2
Comfort	—	3

Rationale:

1 OSHA – as the OSHA limits are set based on formaldehyde being an eye, nose and throat irritant, it is considered reasonable to use them as safety limits in this standard.

2 The World Health Organisation Guidelines for Air Quality, Geneva 2000, maximum guideline for exposure to this chemical as judged by nose and throat irritation in humans.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.12.3 Measurement method

Chemical analysis for formaldehyde involves direct extraction from solid and liquid samples while absorption and/or concentration by active (filtration) or passive (diffusion) sampling is necessary for air samples. The most widely used methods of analysis are based on photometric determination. Low concentrations in air can be detected, after appropriate absorption, by means of high-performance liquid chromatography.

CAS-No. 50-00-0

Method:

— Sampling: Solid sorbent tube (2-hydroxymethyl) piperdine on XAD-2);

— Desorption: Toluene;

— Measurement: GC/FID;

— Quantification limit: 0,3 mg/m^3 (sampling volume: 10 l);

— Accuracy: not determined.

Reference: NIOSH, No. 2541 (1994)

Method:

— Sampling: Solid sorbent tube (2,4-Dinitrophenylhydrazone on silicagel);

— Desorption: Acetonitrile;

— Measurement: HPLC, UV detector, 365 nm;

— Quantification limit: 0,011 mg/m^3 (sampling volume: 6 l);

— Accuracy: ± 11,9 %.

Reference: DFG (German Research Foundation) (1996)

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method.*

4.13 Benzene

4.13.1 General

Benzene is a tracer compound for fuel and exhaust gases. Under normal-in flight operating conditions, only trace amounts of fuel and exhaust gases are present in the bleed air supply. Under certain ground conditions, such as proximity to other aircraft with engines/APU running or using the APU with a tailwind, ingestion by the engines or APU of fuel vapours and exhaust gases can occur.

4.13.2 Requirements and rationale

	Limits	**Rationale**
Safety	3,2 mg.m^{-3} (1 ppmv) (TWA 8 h)	1
Health	12,8 mg.m^{-3} (4 ppmv) (15 min)	2
Comfort	—	3

Rationale:

1 & 2 EU guidelines 97/42/EG

EU-TLVs are technical directional concentrations established by the EU Committee for Hazardous Substances. They apply in particular to carcinogenic substances or substances suspected of being carcinogenic, for which no scientifically justified threshold limit values can be given. The establishment of these values is based on the following:

– the present state of the art, in particular with respect to process engineering and air-conditioning

– the state of the art of metrology, in particular with respect to analytical determination of the concentration of substances

– experience in the field of industrial medicine and toxicological findings.

These must not be in conflict with the technical directional concentrations.

3 The odour threshold is above the health limit and, in the absence of any other comfort issues, a limit is not defined.

4.13.3 Measurement method

CAS-No. 71-43-2

Method:

— Measurement: Portable GC with Photoionization detector;

— Quantification limit: 0,03 ml/m^3;

— Accuracy: ± 27 %.

Reference: NIOSH, No. 3700 (1994)

Method:

— Sampling: Solid sorbent tube (charcoal);

— Desorption: Carbon disulfide;

— Measurement: GC/FID;

— Quantification limit: 0,12 mg/m^3 (sampling volume: 40 l);

— Accuracy: ± 4,1 %.

Reference: BIA (Institute for Occupational Safety, Germany) No. 6265 (1989)

EN ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling (ISO 16017-1:2000).*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID*.

4.14 Toluene

4.14.1 General

In this standard, toluene is used as a tracer compound for solvents. Small quantities of toluene may be present in the cabin air due to off-gasing.

4.14.2 Requirements and rationale

	Limits	Rationale
Safety	760 mg/m^3 (200 ppmv) (15 min exposure)	1
Health	190 mg/m^3 (50 ppmv) (8 h exposure)	2
Comfort	153 mg/m^3 (40 ppmv)	3

Rationale:

1 EU short-term exposure (15 min reference period); EU-Guidelines 97/42/EG.

2 EU long-term exposure (8 hr reference period); EU-Guidelines 97/42/EG.

3 Maximum odour threshold.

4.14.3 Measurement method

EN ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling (ISO 16017-1:2000).*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID.*

4.15 Methylene Chloride (dichloromethane)

4.15.1 General

In this standard, methylene chloride is used as a tracer compound for solvents. Small quantities of methylene chloride may be present in the cabin due to off-gassing.

4.15.2 Requirements and rationale

	Limits	Rationale
Safety	< 3 $mg.m^{-3}$ (0,86 ppmv) over a 24 hr period	1
Health	< 3 $mg.m^{-3}$ (0,86 ppmv) over a 24 hr period	2
Comfort	—	3

Rationale:

1 & 2 A limit of 3 $mg.m^{-3}$ over a 24 hr period has been set by the World Health Organisation Guidelines for Air Quality, Geneva, 2000, as the exposure guideline to prevent the build-up of carboxyhaemoglobin resulting from the production of carbon monoxide as a product of the metabolism of methylene chloride.

3 Comfort limits cannot be defined. Comfort is covered by the health limit and there is much individual variability.

4.15.3 Measurement method

Analytical methods are available for the determination of methylene chloride in biological media and environmental samples. All methods involve gas chromatography in combination with a suitable detector.

CAS-No. 75-09-2

Method:

— Sampling: Solid sorbent tube (charcoal);

— Desorption: Carbon disulfide;

— Measurement: GC/FID;

— Quantification limit: 1,5 mg/m^3 (sampling volume: 40 l);

— Accuracy: ± 3,2 %.

Reference: NIOSH, No. 1005 (1998), BIA (Institute for Occupational Safety, Germany) No. 7000 (1989)

EN ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling (ISO 16017-1:2000).*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID*.

4.16 Endotoxins

4.16.1 General

Endotoxins are part of the outer membrane of Gram-negative bacteria and are present ubiquitously in the environment. The source of these bacteria is normal shedding from the aircraft occupants.

4.16.2 Requirements and rationale

	Limits	Rationale
Safety	—	1
Health	50 Endotoxin Units/m^3 (4,5 ng.m^{-3}) over an 8 hr exposure period For short durations, peak value, and depending of the relevant health effect, no-effect levels range from 9 ng/m^3 to 170 ng/m^3	2
Comfort	—	3

Rationale:

1 Acute exposure to endotoxins is not a safety issue.

2 Dutch Expert Committee on Occupational Standards of the National Health Council proposed health-based recommended limit value.

3 Comfort limits cannot be defined.

4.16.3 Measurement method

Environmental monitoring is usually performed by sampling airborne dust and subsequent analysis of aqueous extracts by using a Limulus Amebocyte Lysate assay.

4.17 Bacteria, viruses and fungi

Bacteria, viruses and fungi may be present in the cabin air. The sources may be the cabin occupants themselves or may be present in the outside air.

	Limits	Rationale
Safety	—	1
Health	—	2
Comfort	—	3

Refer to Annexes B and C.

5 Environmental criteria

5.1 Thermal conditions

5.1.1 Requirements and rationale

Safety and Health

The NIOSH recommendations document, 'Occupational Exposure to Hot Environments', states in section 3 'Heat Balance and Heat Exchange' that an essential requirement for continued normal body function is that the deep body core temperature be maintained within the acceptable range of about (37 ± 1) °C [(98,6 ± 1,8) °F)]. In section 8, 'Basis for recommended Standard', the WHO recommendations are referenced, which state that core body temperature should not exceed 38 °C 'in prolonged daily exposure to heavy work'.

Comfort

In Fanger 'Thermal Comfort', chapter 3 'The influence of certain special factors on the application of the comfort equation', there is a section entitled 'Air pressure'. After considering several small effects, it concludes that up to 30 % change equivalent to 3 000 m only small corrections are necessary. 'The comfort equation can therefore be applied without modifications as a reasonable approximation in these cases. At low air pressures a greater humidity dependency can be expected.'

ASHRAE delivers a comfort tool based on Fanger's theory in which air pressure is included. Applying the tool for normal comfort conditions, no influence on PMV and DR was found changing the air pressure from 101 kPa to 75 kPa.

Thermal comfort is globally defined in EN ISO 7730 using PMV (predicted mean vote) and PPD (percentage people dissatisfied) indices. These indices take into account the combination of activity and clothing of the people, plus ambient parameters such as temperature, humidity and air velocity. This means that for the same range of PMV/PPD values, the corresponding range for temperature, humidity and velocity can differ according to activity and clothing. This is why in the following a difference is made between passengers, cabin crew and flight crew.

The required value for global thermal comfort is:

$$-\mathbf{0,7} < \mathbf{PMV} < \mathbf{0,7};\ \mathbf{PPD} < \mathbf{15\ \%}$$

This is only valid within limits required value for vertical temperature gradient and radiant temperature asymmetry, specified in Table 2.

The requirement concerning draft risk (DR) is set at level of < 15 %.

For guidance about corresponding ranges for operative temperatures and air velocities, see Annex D.

Other criteria concerning thermal comfort parameters are shown in Table 3.

Table 2 — Temperature gradient and radiant temperature asymmetry

Vertical temperature Gradient °C/m	**Radiant temperature asymmetry** °C
3,5 (0,1 m to 1,1 m height)	Horizontal: < 10 Vertical: < 5

However during ground and flight operations.

5.1.2 Measurement methods

The determination of the indices listed in the previous paragraph requires the measurement of the following parameters:

— air temperature;

— air velocity;

— radiative temperature;

— relative humidity.

The measurement methods and the measurement apparatus used to determine these parameters should comply with the standard ISO 7726. Concerning the particular case of the aircraft cabin environment, the locations for the different measurements are described in Table 3. Some requirements concerning the apparatus are given in Table 4.

Table 3 — Locations of measurement points for thermal environment

Parameters	**Measurement locations**
Air Temperature Globe Temperature Relative Humidity Air Velocity	Stationary points: Ankle height: 0,1 m from floor Head height of seated passenger: 1,1 m from floor One seat tested in each class (economy and business) Mobile traverses: Head height of seated passenger: 1,1 m from floor Over a random sample of 15 % of the seats in each class

Table 4 — Measurement apparatus requirement for thermal environment

Parameter	Range	Resolution	Accuracy	Response time
Air Temperature (at least 2 pts.)	10 °C to 50 °C	0,1 °C	± 0,2 °C	< 10 s
Globe Temperature	0 °C to 60 °C	0,1 °C	± 0,2 °C	< 10 s
Relative Humidity	0 % RH to 100 % RH	0,1 % RH	± 1 % RH (10 % RH to 90 % RH, ± 2 % RH (remaining range)	< 20 s
Air Velocity	0 m/s to 1,5 m/s	0,01 m/s	± 5 %	< 0,5 s

5.2 Rate of change of cabin altitude

5.2.1 Requirements and rationale

Safety: No limit.

Health and comfort: 500 sea level feet per minute (slfpm) for decreasing pressure (increasing altitude) 300 slfpm for increasing pressure (decreasing altitude).

Rationale:

Comfort limits are based on physiological factors related to the speed at which the ear can compensate the pressure difference between ambient pressure and pressure of the air within the Eustachian tubes. Each person will be more or less sensitive to these changes so the comfort limits also form the basis of the health limits. As for safety, if there is a rapid pressure change in the aircraft cabin, it is likely to be due to a system or structural failure. In this case, the rates of change cannot by definition be controlled any more so there is no sense in setting maximum rate of change limits.

5.2.2 Measurement methods

Only one point of measurement in the cabin is required. The position is not critical, as the pressure should be uniform throughout the cabin.

Table 5 — Measurement apparatus requirement for pressure

Parameter	Range	Resolution	Accuracy	Response time
Absolute Pressure	0-1 bar	0,001 bar	± 0,005 bar	< 2 s

Annex A
(informative)

Altitude corrections for volume concentrations

The allowable volumetric concentration [X] at a given cabin altitude can be calculated from the allowable volumetric concentration at sea level via the pressure ratio P_0/P, where P is the cabin pressure and P_0 is the pressure at sea level: $[X]_{\text{cabin altitude}} = [X]_{\text{sea level}} \times (P/P_0)$.

The following table gives some representative values of the ratio (P_0/P) for a constant temperature.

Table A.1

P at	(P_0/P)
5 000 feet	1,20
6 000 feet	1,25
7 000 feet	1,30
8 000 feet	1,35

NOTE Corrections required to account for the range of cabin air temperatures mentioned in this standard (ref paragraph dealing with temperature range for comfort) are less than 2 %.

Annex B
(informative)

Bacteria, fungi and viruses

B.1 Guidelines

B.1.1 Safety

Acute exposure to micro-organisms is not a safety issue.

B.1.2 Health

Although several attempts have been made to set maximum permissible levels of fungi, bacteria and viruses in the indoor environment, there is no widely accepted standard value(s), even in the building industry. However, one European guideline suggests that the level of micro-organisms in the workplace should be ≤ 500 cfu.m^{-3} (by ventilation, 24h), ref [2].

Wanner and al [ref 1] proposed a series of guideline categories for aerial concentration of fungi and bacteria, developed under the European Collaborative Action programme; these are given in the table below. However, the concentrations below are not indicative of the risk of acquiring infection in susceptible individuals.

Table B.1 — Environmental categories for mixed populations of fungi and bacteria in non-industrial indoor environments [ref 1]

Category	Fungi cfu.m^{-3}	Bacteria cfu.m^{-3}
Very Low	< 25	< 50
Low	< 100	< 100
Intermediate	< 500	< 500
High	< 2 000	< 2 000
Very High	> 2 000	> 2 000

References

[1] Wanner H-U, Verhoeff A, Colombi A, Flannigan B, Gravesen S, Mouileseaux A, Nevalainen A, Papadakis J and Seide K. Biological particles in Indoor Environments. European Collaborative Action, Indoor air quality and its impact on man. Commission of the European Communities, Luxembourg, 1993.

[2] 'Guidelines workplace, Germany' according EU-frame-guidelines 89/391; BIA's report 2/95 'Indoor Air Quality', Germany.

B.1.3 Comfort

Acute exposure to micro-organisms is not a comfort issue.

B.2 Measurement Method

Measurement should be taken at the air exit from the individual air outlets (if these are fitted) or at the air inlets to the cabin.

Measurement method using MB2 Microbiological Aerosol Samplers to take air sample onto an agar plate for sending to a laboratory.

For additional information regarding the current technological solution for the removal of bacteria and viruses, please refer to Annex C.

Annex C
(informative)

Technical information for bacteria, viruses and other particulate contamination removal

C.1 Introduction

This standard is performance based and not solution based, therefore the technologies for removing bacteria, viruses and other particulate matter have not been addressed in the main part of this standard.

C.2 Cabin Air Recirculation System

In the majority of modern commercial aircraft, the air supplied into the cabin via the environmental control system (ECS) uses a mixture of outside air and recirculated air. Air for recirculation can be taken from the general space above the passengers, from the cabin outlet, or from the air volume under the cabin floor

The cabin air recirculation system shall ensure that the levels of particulate contamination re-entering the aircraft cabin are below the levels defined in this standard and not worse than the external ambient conditions, outside of the aircraft

Currently, the levels defined for bacteria, fungi and virus micro-organisms and the levels defined for particulate contamination may be achieved by the installation of HEPA filter elements (equal to or greater than EU grade H13) on the recirculation air line within the environmental control system.

This level of filter element removal efficiency shall effectively prevent transmission of diseases through the recirculation system by stopping airborne pathogenic microbes (microbes include bacteria and viruses) on the first pass.

Note that these cabin air recirculation filter elements do not prevent the possibility of direct person to person transmission within the aircraft cabin.

NOTE As defined in European Standard EN 1822-1:1998.

HEPA filter = High Efficiency Particulate Air filter, classes H10 to H14 (85 % to 99,995 % efficiency).

For aircraft cabin air recirculation systems, this definition has been tightened and the typical aerospace industry standard for new build production aircraft is EU Class H13, i.e. 99,99 % minimum removal efficiency by sodium flame test (Eurovent 4/4, BS3928). This is equivalent to 99,97 % minimum removal efficiency at 0,3 µm when tested according to IEST Recommended Practice RP-CC001.3 ‘HEPA and ULPA Filters’ (IEST, Institute of Environmental Sciences and Technology 1997).

C.3 Independent references

[1] The World Health Organisation (www.who.int), “Summary of SARS and air travel”, dated 23 May 2003.

[2] The World Health Organisation (www.who.int), “Tuberculosis and Air Travel”, dated 1998.

[3] The SAE Aerospace Information Report AIR 4766 – “Air Quality for Aircraft Cabins”.

[4] The UK House of Lords Report, “Air Travel and Health”, dated November 2000.

[5] Centers for Disease Control, “Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care facilities, 1994”.

Annex D
(informative)

Measurement method for micro-organisms

D.1 Introduction

This is an informative annex related to bacteria and fungi. For these, if desired, measurements can be carried out according to the methods described below. A virus is not a micro-organism and the reader may wish to consult other sources to evaluate measurement for viruses.

D.2 General

Bacteria are classified as prokaryotic micro-organisms, while fungi are eukaryotic micro-organisms. Both are ubiquitous in nature and play an important role in the natural cycle of matter by breaking down and mineralising organic material. Bacteria/fungi occur in various human workplaces and communal areas, and may sometimes reach air concentration levels, which are considerably higher than reference values in outside air. Bacteria/fungi occur as single cells or cell aggregates and are often bound up in dust particles or suspended in droplets.

The typical diameter of vegetative bacteria cells is less than 1 µm with a typical length of 1-5 µm. The diameter of fungi (airborne spores) is generally 2-8 µm.

General aspects to bear in mind when conducting measurements:

Variations in exposure concentrations: Variations in exposure concentrations of micro-organisms are caused by the fact that the release of micro-organisms into the air from different sources differs over time and space and is therefore not uniform.

Calculating the background load: When conducting measurements in closed communal areas, the background load should always be calculated using reference measurements in the outside air. The reference measurement shall invariably be taken using the same measurement strategy as in the closed communal area.

Determination of exposure peaks: When selecting the measurement method for determining exposure peaks, particular care should be taken to choose a sampling regime suited to the duration of the exposure peaks. Measurements should be taken before and after the occurrence of exposure peaks to ensure that the maximum concentration of bacteria and fungi in comparison to average exposure levels is recorded.

D.3 Measurement principle

D.3.1 General

A defined volume of air is drawn through a membrane filter with the aid of a pump integrated in the collection device or connected to the sampling head, and the bacteria/fungi are collected on the filter. Two different methods of analytical determination, both based on cultivation of the bacteria/fungi, can be used.

D.3.2 Cultivation, direct method

After use, the filters are laid directly onto the culture medium, incubated and a count is performed.

D.3.3 Cultivation, indirect method

The bacteria/fungi collected on the filters are first placed in solution and then subjected to serial dilution before being applied to the culture medium. They are then incubated and a count is performed.

The cultivation methods essentially consist in growing the live, reproducible bacteria/fungi on suitable culture media, which permit the growth of as many different species as possible. The determination limit of the measuring method depends on the analytical method selected (direct, indirect method) and the sampling procedure chosen (flow volume, filter diameter).

D.4 Sampling

D.4.1 General

It is advisable to use sampling devices that collect particles/aerosols in accordance with the conditions set out in EN 481 ‘Size fraction definitions for measurement of airborne particles’ (inhalable fraction).

D.4.2 Devices, materials

Sampling devices

— Dust collection head for the inhalable fraction as set out in EN 481 (inhalable fraction).

Filter

— Gelatine membrane filter, cellulose nitrate membrane filter, polycarbonate membrane filter; diameter: 37-80 mm.

D.4.3 Transportation, storage

The used filters must be protected from sunlight, excessively humid or dry conditions, heat and dust and be taken to the laboratory as soon as possible for analysis, usually on the day of sampling. The ambient temperature shall not be allowed to exceed the incubation temperature, which will subsequently be used. Transportation and storage conditions shall be documented, particularly in cases where potential effects on the results cannot be ruled out.

D.5 Analysis

D.5.1 Cultivation, direct method

D.5.1.1 General

This method is used to determine the average concentration of reproducible bacteria/fungi found during the sampling period in the workplace or communal area on a person- or location-related basis. The result is expressed in colony-forming units per unit of air (= cfu.m^{-3} air). Once the used filter has been placed on a suitable culture medium, the reproducible bacteria/fungi grow into colonies. The gelatine membrane filters dissolve, while the other types of membrane filter (cellulose ester, polycarbonate) become saturated by absorbing the culture medium.

D.5.1.2 Equipment, material

— Autoclave for steam sterilisation;

— Incubator;

— Binocular stereomicroscope (magnification 2-40x).

The following culture medium is recommended for bacteria determination:

Casein-soymeal-peptone (CASO) agar: Thanks to its rich composition, universal agar offers a growth medium for numerous micro-organisms and even permits the cultivation of more difficult micro-organisms. Actidion is used to suppress the growth of fungi, which is necessary in order to be able to determine concentrations of bacteria in fungi-infested areas, e.g.

— Peptone from casein 15,0 g/l
— Peptone from soymeal 5,0 g/l
— Sodium chloride 5,0 g/l
— Actidion (cycloheximide) 0,3 g/l
— Agar 16,0 g/l
— pH 7,3 ± 0,3

The following culture medium is recommended for fungi determination:

Dicloran glycerol (DG-18) agar: Selective identification of xerophile fungi. The use of chloramphenicol will prevent bacterial growth. Glycerol reduces water activity. Dichloran prevents the filamentous fungi from spreading. Composition of DG-18 agar:

— Peptone 5,0 g/l
— Glucose 10,0 g/l
— Potassium hydrogen phosphate 1,0 g/l
— Magnesium sulfate 0,5 g/l
— Dichloran (=2,6-dichloro-4-nitroaniline) 0,002 g/l
— Chloramphenicol 0,1 g/l
— Glycerol 18 % vol.
— Agar 15,0 g/l
— pH 5,6 ± 0,2

D.5.1.3 Method

The sampling time should be a minimum of 1 minute, and for bacteria should not exceed 10 minutes. Incubation takes place in an incubator for 7 days at 30 °C for bacteria and 25 °C for fungi. Because of the possibility of high concentrations, the first count should be performed after 24 hrs using a stereomicroscope. After counting the colonies, which have grown on each plate, the result is expressed in colony-forming units per m^3 air using the following formula:

$$\text{Cfu.m}^{-3} = \frac{\text{colonies / plate} \times 1000\ \text{(l)}}{\text{Sampling volume (l)}}$$

D.5.2 Cultivation, indirect method

This method should be used when wide variations in air concentrations are expected. In principle, the bacteria/fungi collected on the filter are dissolved (in a salt solution). A serial dilution procedure is then carried out. The method is the same as that set out in D.5.1.

D.6 Determination limits

D.6.1 Bacteria

Filtration/direct method:

— Lower determination limit [2)] 10 cfu.m^{-3}

— Upper determination limit 17 000 cfu.m^{-3}

Filtration/indirect method:

— Lower determination limit [2)] 200 cfu.m^{-3}

— Upper determination limit no limit

D.6.2 Fungi

Filtration/direct method:

— Lower determination limit [2)] 10 cfu.m^{-3}

— Upper determination limit 8 500 cfu.m^{-3}

Filtration/indirect method:

— Lower determination limit [2)] 1 000 cfu.m^{-3}

— upper determination limit no limit

D.6.3 Literature

[1] Verfahren zur Bestimmung der Schimmelpilzkonzentration in der Luft am Arbeitsplatz (‘Method for the determination of fungi concentration in the air at the workplace’); dated August 2001, BIA work folder No. 9420; published by: Berufsgenossenschaftliches Institut für Arbeitsschutz (Institute for Occupational Safety) (BIA), Erich Schmidt, Bielefeld.

[2] Verfahren zur Bestimmung der Bakterienkonzentration in der Luft am Arbeitsplatz (‘Method for the determination of bacteria concentration in the air at the workplace’); dated April 1997, BIA work folder No. 9430; published by: Berufsgenossenschaftliches Institut für Arbeitsschutz (Institute for Occupational Safety) (BIA), Erich Schmidt, Bielefeld.

Findings from the following literature have also been taken into account:

[3] Blomquist, G: Sampling of biological particles. Analyst 119 (1994).

[4] ASTM: Standards on materials and environmental microbiology: Practice for sampling airborne micro-organisms; E 884-82; Philadelphia 1993.

[5] Griffiths, W.D.: Report on bioaerosols workshop European aerosols conference, Oxford 1992. J. Aerosol Sci. (1993).

[6] EC Directive 90/679/EEC: Protection of workers from risks related to exposure to biological agents at work. Amended version: EC Directive 93/88/EEC.

2) The lower determination limit depends on volume flow and filter diameter.

Annex E
(informative)

Operative temperature and air velocity ranges

The following table gives guidance for the different occupant categories about air velocities and operative temperature.

Table E.1 — Air velocity and operative temperature ranges

Categories of people	**Activity** (Met)	**Clothes** (Clo)	**Air velocity** (m/s)	**Operative temperature range** (°C)
Passengers	1	1	0,15	22,0 to 27,0
			0,30	22,5 to 27,0
Cabin crew / Flight crew	1	0,75	0,15	23,5 to 28,0
			0,30	24,0 to 28,0
		1	0,15	22,0 to 27,0
			0,30	22,5 to 27,0
	1,6	0,75	0,15	17,5 to 25,0
			0,30	18,5 to 25,5
		1	0,15	15,0 to 25,5
			0,30	16,0 to 24,0

NOTE As the relative humidity has a low influence on the PMV value within the range of temperature listed here, then the guidance given in this annex should still valid even if the humidity in the aircraft cabin is lower than 30 %.

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