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Space systems — Human-life activity support systems and equipment integration in space flight — Techno-medical requirements for space vehicle human habitation environments — Requirements for the air quality affected by harmful chemical contaminants

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operation.*

Introduction

This document regulates operation of systems removing harmful air contaminants from manned spacecraft and habitable modules, necessary for crew life support on a space mission.

This document is considered to be the 3rd level standard according to ISO 17763 and ISO 16157 (which is the 2nd level standard). It is also a part of the latter document.

This document establishes requirements for measurements of air quality affected by harmful chemical contaminants. Systems that remove harmful air contaminants out of manned spacecraft and habitable modules (as a part of life crew support system) sustain the process of air quality control.

The document's goals are:

— to elaborate integrated technical and medical requirements for air quality and harmful chemical contaminants for designers who develop systems of harmful air contaminants' removal from astronaut-inhabited aircrafts and modules;

— to maintain air quality for astronauts (control of harmful chemical contaminants); and

— to elaborate integrated technical and medical requirements for medical staff in order to control air quality and harmful chemical contaminants in it and support a crew life system.

Space systems — Human-life activity support systems and equipment integration in space flight — Techno-medical requirements for space vehicle human habitation environments — Requirements for the air quality affected by harmful chemical contaminants

1 Scope

This document is a 3rd level standard with respect to ISO 17763 and is a 2nd level standard with respect to ISO 16157.

This document establishes environmental conditions for spacecraft air quality, including harmful chemical contaminants and requirements for harmful air contaminants' removal systems.

NOTE These systems support stated environmental conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 17763, *Space systems — Human-life activity support systems and equipment integration in space flight*[1)]

ISO 16157, *Space systems — Human-life activity support systems and equipment integration in space flight — Techno-medical requirements for space vehicle crew habitation environments*[2)]

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
human habitation environment in spacecraft
complex issue that involves material, energy and information flows, as well as elements formed in SC habitable compartments

Note 1 to entry: Such elements are derived from life activity processes, human social-labour processes, space factors, space mobility, and hardware functioning processes, including the ones designed to arrange humans' interaction with the habitation environment in order to provide specified conditions for human life activity in space flights.

[SOURCE: ISO 17763, 3.1]

1) Under preparation.

2) Under preparation.

3.2
human living conditions in SC
complex of human habitation environment parameters in SC, providing health maintenance, human safety and keeping of his ability to work at a level needed to execute the planned work program

[SOURCE: ISO 17763, 3.2]

3.3
techno-medical requirements for human habitation environments
complex of biomedical, hygiene/sanitary, ergonomic and design issues

Note 1 to entry: Those requirements take into account physiological and social-psychological human needs in the process of hardware development and operation in order to guarantee specified living conditions aboard space systems.

[SOURCE: ISO 17763, 3.3]

3.4
manned (habitable) spacecraft
MSC
spacecraft, spaceship, space station, Lunar or planetary base with pressurized components inside which human habitation environment is maintained

[SOURCE: ISO 16157, 3.4]

3.5
life support systems
LSS
systems supporting mass and energy exchange between space traveller's body and habitable environment inside MSC

[SOURCE: ISO 16157, 3.5]

3.6
extravehicular activity
EVA
spacesuited activities outside MSC

[SOURCE: ISO 16157, 3.6]

3.7
harmful chemical contaminants
gaseous contaminants in habitable environment of a manned spacecraft or module, causing toxic effect on humans

3.8
limiting permissible concentration
LPC
safe concentration of harmful (toxic) substance in the air at a given mission duration for nominal conditions

Note 1 to entry: This concentration determines a «zero risk» level.

3.9
maximum allowable concentration
MAC
safe concentration of toxic substance in the air at a given mission duration for off-nominal conditions and emergency situations

Note 1 to entry: This concentration determines an «acceptable risk» level

3.10
maximum permissible concentration for single dose
MPC_{SD}
concentration of toxic substance in the air in emergency situations for single dose and different duration, which guaranty human health maintenance

4 Symbols and abbreviated terms

CAS (CAS#)	Chemical Abstracts Service Registry Number www.cas.org for chemicals unique identification
SS	Space Systems
SC	Spacecraft

5 Application of this document in space programs

5.1 General

Implementation of space programs and integration with human life activity shall be considered at all levels — from individual components to full integration.

5.2 This document applicability

All requirements stated in this document, unless otherwise specified, shall be applicable to all phases of the flight program.

5.3 Specific program requirements

Each human space flight program shall establish its specific requirements for development of this document. These requirements shall be verifiable.

5.4 Monitoring of the flight program compliance to this document

Each human space flight program shall be a subject to permanent monitoring to verify compliance with this document, including design, development, tests, and operation.

5.5 Verification of program requirements

Each human space flight program shall be verified for requirements in accordance with this document.

6 Air quality control according to contaminants

6.1 General

This document is a third level standard with respect to first level standard ISO 17763 and second level standard ISO 16157.

All human-life activity support systems and equipment integration in space flight shall be in accordance with the requirements of ISO 17763, ISO 16157 and this document.

This document covers all space missions with in-flight stay duration continuously up to 3 years.

This document contains environmental parameters specifications for flights with a human continuous stay for a week, a month, a year and three years in nominal conditions, and for a human continuous stay in case of emergency up to 1 h, 6 h and 24 h.

The given document defines air quality in MSC by gaseous toxic contaminants content.

Toxic gaseous contaminants' emission in MSC air is caused by humans themselves, non-metallic equipment (including packing equipment), scientific equipment containing toxic gases and toxic evaporating liquids, personal belongings, and medical means.

The daily rates of human excreted harmful gas contaminants shall be taken in accordance with Annex A.

Air quality and harmful chemical contaminants control in MPC is provided by systems of harmful contaminants' removal (which are a part of life support systems) and MCS launch operations.

According to toxicological criteria of harmfulness contaminants, they can be divided into 4 groups: very toxic, toxic, low-toxicity and slightly toxic. The smaller concentration of the more toxic contaminant is permitted in MSC air at a given continuous human flight.

NOTE Group conditional division by LPC (at zero risk level):

— less than 0,1 mg/m^3 — very toxic;

— from 0,1 to 1 mg/m^3 — toxic;

— from 1 to 10 mg/m^3 — low-toxicity; and

— over 10 mg/m^3 — slightly toxic.

In cases of severe toxic effect the group is varied and risen.

Air quality is defined by matching the harmful contaminant content and the corresponding toxicological norms. A regular flight admits maximum permissible concentration (MPC) of each contaminant at zero risk and tolerable risk conditions for corresponding continuous man flight.

Nomenclature of harmful contaminants in MSC air includes several orders of hundreds; nomenclature of contaminants meaningful by concentration several orders of tens. Table 1 reflects air quality estimation based on most frequent harmful contaminants. Measurement and addition of other contaminants for estimation in nominal conditions are supplementary.

Table 1 — The main list of toxic contaminants for the estimation of air quality in manned modules at duration of continuous flight: 180 d, 360 d (1 year) and 1 100 d (3 years)

Compound	CAS#	Flight duration					
		180 d		360 d		1 100 d	
		LPC mg/m^3	MAC mg/m^3	LPC mg/m^3	MAC mg/m^3	LPC mg/m^3	MAC mg/m^3
Hydrogen[a]	1333–74–0	340	1 600	340	1 600	340	1 600
Methane[a]	74–82–8	3 500	3 500	3 500	3 500	3 500	3 500
Pentane	109–66–0	10,0	200,0	10,0	200,0	10,0	200,0
Hexane	110–54–3	5,0	100,0	5,0	100,0	5,0	100,0
Heptane	142–82–5	10,0	100,0	10,0	100,0	10,0	100,0
Formaldehyde	50–00–0	0,05	0,12	0,05	0,12	0,05	0,05
Acetaldehyde	75–07–0	1,0	4,0	1,0	4,0	1,0	4,0
Aliphatic Aldehydes (Benzaldehyde)	100–52–7 etc.	1,0	8,0	1,0	4,0	1,0	4,0

Content of contaminants between LPC ("Zero risk" level) and MAC ("Acceptable risk" level) shall be limited by time.

NOTE Compounds are grouped by structural classes

[a] Monitored for engineering operations only (are not toxic impurities, specifications are established on fire danger and explosion hazard).

Table 1 *(continued)*

Compound	CAS#	Flight duration					
		180 d		360 d		1 100 d	
		LPC mg/m³	MAC mg/m³	LPC mg/m³	MAC mg/m³	LPC mg/m³	MAC mg/m³
2-Propenal (Acrolein)	107–02–8	0,02	0,02	0,02	0,02	0,02	0,02
Methanol	67–56–1	0,2	90	0,2	90	0,1	30
Ethanol	64–17–5	10,0	2 000	10,0	2 000	10,0	2 000
2-Propanol (isopropyl alcohol) (isopropanol)	67–63–0	1,5	150	1,5	150	1,5	100
1-Butanol	71–36–3	0,8	40,0	0,8	40,0	0,5	30,0
Acetone	67–64–1	2,0	52,0	2,0	52,0	1,0	25,0
2-Butanone (Methyl ethyl ketone)	78–93–3	0,25	30,0	0,25	30,0	0,15	20,0
Benzene (benzol)	71–43–2	0,2	0,2	0,2	0,2	0,04	0,04
Toluene (Benzene, methyl-) (Toluol)	108–88–3	8,0	15,0	8,0	15,0	8,0	15,0
Xylenes	1330–20–7 etc.	5,0	37,0	5,0	20,0	3,0	6,5
Styrene (Benzene, ethenyl-) (Styrol)	100–42–5	0,25	0,5	0,25	0,5	0,15	0,3
Isopropyl Benzene (Cumol)	98–82–8	0,5	1,0	0,5	1,0	0,25	0,5
Furan	110–00–9	0,05	0,07	0,05	0,07	0,02	0,04
Ammonia	7664–41–7	2,0	2,0	1,0	2,0	1,0	2,0
Ethyl Acetate	141–78–6	4,0	10,0	4,0	10,0	4,0	10,0
Carbon Monoxide	630–08–0	5,0	10,0	5,0	10,0	5,0	10,0
Polymethylcyclosiloxanes	541–02–6 541–05–9 556–67–2 107–51–7 etc.	0,2	9,0	0,2	5,0	0,2	2,0
Trimethylsilanol	1066–40–6	0,2	4,0	0,2	4,0	0,2	4,0
Dichloromethane	75–09–2	5,0	10,0	5,0	10,0	5,0	10,0
1,2-Dichloroethane	107–06–2	0,5	1,0	0,5	1,0	0,5	1,0
Freon 218	76–19–7	150	3 000	150	3 000	150	3 000

Content of contaminants between LPC ("Zero risk" level) and MAC ("Acceptable risk" level) shall be limited by time.

NOTE Compounds are grouped by structural classes

[a] Monitored for engineering operations only (are not toxic impurities, specifications are established on fire danger and explosion hazard).

6.2 Substance estimation by toxicological group

Substances should be estimated by toxicological groups by T factor in consistency with the following equation:

$$T = C_1/L_1 + C_2/L_2 + \ldots C_n/L_n$$

where

$C_{1\ldots n}$ is the average concentration during flight;

$L_{1\ldots n}$ is the LPC for zero risk level (or MAC for acceptable risk level);

n is the number of couplings in a group.

The air is considered to be allowable if T amount for each type of toxic impact is less than 1–5 for zero risk level and less than 1 for acceptable risk level.

6.3 Evaluation of toxic contaminants

Very toxic and toxic contaminants shall be evaluated, as well as toxic chemicals by their toxicity, and then either restrict or prohibit their use in MSC.

6.4 Requirements for non-metallic materials and their selection for use in manned modules

6.4.1 Non-metallic materials shall not evolve to the air volatile chemical compounds with concentrations which can give direct or indirect injurious (adverse) effect to human organism with a glance of combined effect of total gas complex.

6.4.2 The selection of most favourable in regard to hygienic materials is provided by analysing a summary list of non-metallic materials which are used in manned spacecraft and by laboratory testing specimen of materials. Sanitary-hygienic testing of the materials shall be done according to instructional lines on sanitary-chemical and toxicological testing of non-metallic materials.

6.4.3 Aging could reduce off-gassing. Aging is effective with longer in time and higher in temperature. Practical aging condition should be assessed considering material type, manufacturing process, maximum usable temperature, project schedule, etc.

6.4.4 Choosing the materials shall take into account that the content and level of off-gassing components of non-metallic materials depends on the following main factors:

— formulation and manufacturing technique of materials;

— quantity of materials in pressurized volume;

— ambient temperature;

— period of aging between manufacturing of the materials and start of usage;

— service duration of materials in pressurized volume;

— efficiency of life support systems (LSS);

— operational temperature; and

— material usage configuration.

6.4.5 For equipment of pressurized modules, non-metallic materials shall not be used, where offgasing products are in an extremely high toxicity group of substances. These products are: Benzo[a]pyrene (CAS# 50-32-8), Benzidine (CAS# 92-87-5), 2-Aminonaphthalene (CAS# 91-59-8), N-Nitrosodimethylamine (CAS# 62-75-9), β-Propiolactone (CAS# 57-57-8), p-Dimethylaminoazobenzene (CAS# 60-11-7), Dimethylsulfate (CAS# 77-78-1), Arsenic (CAS# 7440-38-2), Beryllium (CAS# 7440-41-7).

7 Air quality control according for carbon dioxide

Carbon dioxide is the prime substance excreted by a human's skin and lungs.

Design value for day average CO_2 excreted by human accepting 480 normal litres (nl) of CO_2 per day (0,96 kg/day) or 20 nl/h.

Carbon dioxide is the gas needed for human life activity since it stimulates our respiratory centre. The increase of CO_2 concentration leads to acceleration of breathing and therefore increases inflow of oxygen to the lungs. CO_2 concentration in human's alveolus pulmonis is 40 mmHg.

Design value for Earth atmosphere air — 0,23 mmHg (0,03 vol.%). A human almost does not feel CO_2 concentration in air up to 1,5 vol.% to 2,0 vol.% (11,5 mmHg to 15,2 mmHg) practically. It based on 40 mmHg "barrier" in lungs.

Day average limit of CO_2 level for 1 year human flight — 6 mmHg (0,8 % vol.) and for 3 year flight — 5,3 mmHg (0,7 % vol.)

Short period increase of CO_2 concentration is allowed up to 7,6 mmHg (1 % vol.).

Emergency CO_2 concentration — 20 mmHg (2,6 % vol.).

8 Air quality control during ground processing for MSC and habitable modules

During on-ground processing before launch, a new habitable module after integration equipment and cargos not less than 80 % module shall be purged with clean air then enclosed for some days for air sampling.

Based on analyses of air samples, it is possible to make a forecast of contaminants concentrations at first human ingress. Concentration of harmful contaminants in the air shall be less "Zero risk" level in Table 1 (optional contaminants of this list can be between "Zero risk" and ""Acceptable risk" level). If air quality is not according to these conditions, then additional purging shall be provided for module with warm air and repeating module pressurization for some days for air sampling. Based on analyses of air samples, it is possible to determine the necessity for additional air purification of module via on-board filters.

9 Air quality control in emergency situations (caused by emission of large amounts of pollutants)

9.1 Three situations shall be considered: nominal (regular and non-normal operation), emergency (emergency operation and temporary astronaut egress) and catastrophic (MSC egress with no possibility to return).

9.2 Catastrophic situation followed by death of a human or their severe injury with further disability should be considered at a ground-based pre-flight assessment only. Such risk on MSC is unacceptable.

9.3 To prevent catastrophe caused by toxic substance emission in MSC air, one shall analyse, restrict and prohibit delivery of toxic cargo in large quantities and provide necessary individual protective equipment.

9.4 Equipment might provoke two emergency situations (1): emission of harmful contaminants in the air due to combustion and charring, and (2) emission of harmful contaminants caused by depressurization.

9.5 During conflagration, it shall be necessary to measure several contaminants on-board according to Table 2, and make sure their concentration does not exceed factors pointed in Table 2.

Table 2 — List of substances and estimation of air quality in emergency situations

Substances	Chemical formula	CAS#	MPC for 1h mg/m³	MPC for 6 h mg/m³	MPC for 24 h mg/m³
Carbon monoxide	CO	630–08–0	1 500	600	230
Methanal (Formaldehyde)	CH_2O	50–00–0	1,0	0,7	0,3
Azane (Ammonia)	NH_3	7664–41–7	210	105	21
Nitrogen oxides	NO NO_2	10102–43–9 10102–44–0	30	20	10
Hydrogen chloride	HCl	7647–01–0	10	7	3
Hydrogen fluoride	HF	7664–39–3	5	2	1
Hydrogen cyanide	HCN	74–90–8	4,0	1,0	0,5