SLOVENSKI STANDARD
SIST-TP CEN/TR 17904:2023

01-januar-2023

Kakovost zraka v kabini civilnih letal - Kemijske spojine

Cabin air quality on civil aircraft - Chemical compounds

Kabinenluftqualität in Verkehrsflugzeugen - Chemische Parameter

Qualité de l'air en cabine d'avions civils - Composés chimiques

Ta slovenski standard je istoveten z: **CEN/TR 17904:2022**

ICS:

13.040.01	Kakovost zraka na splošno	Air quality in general
49.095	Oprema za potnike in oprema kabin	Passenger and cabin equipment

SIST-TP CEN/TR 17904:2023 **en**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER REPORT

CEN/TR 17904

November 2022

ICS 49.095

English Version

Cabin air quality on civil aircraft - Chemical compounds

Qualité de l'air en cabine d'avions civils ¿ Composés chimiques

Kabinenluftqualität in Verkehrsflugzeugen - Chemische Parameter

This Technical Report was approved by CEN on 30 October 2022. It has been drawn up by the Technical Committee CEN/TC 436.

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Ref. No. CEN/TR 17904:2022 E

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European foreword

This document (CEN/TR 17904:2022) has been prepared by Technical Committee CEN/TC 436 “Cabin air quality”, the secretariat of which is held by AFNOR.

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Introduction

Air quality on civil aircraft requires particular attention, given the characteristics of the cabin environment.

An environmental control system (ECS) is used to regulate the aircraft cabin pressure, temperature and ventilation supply air to provide a safe and comfortable environment for the passengers and air crew. The aircraft cabin by design and operation is enclosed and is a densely occupied environment (with only a small amount of per person dilution volume), creating the potential for elevated levels of bio-effluents in the cabin, such as carbon dioxide (see Annex A). ECS architecture on civil passenger aircraft can be broadly separated in two categories: bleed air ECS systems and bleed free ECS systems (see Annex A). Most aircraft manufactured today, and nearly all aircraft in service, have bleed air ECS.

This document focuses on the chemical compounds potentially present in cabin air. It sets out recommendations and supporting annexes to enable airline operators, manufacturers and suppliers to identify - and either prevent or mitigate - exposure to contaminants in the cabin air, with particular emphasis on bleed air contaminants sourced to or generated from engine oil and hydraulic fluid. This includes some limited measures intended to protect workers assigned to troubleshoot and service the aircraft ventilation supply air systems.

NOTE Aircraft accident investigation agencies, aviation regulators from the EU and US, and the International Civil Aviation Organization (ICAO) have recognized that bleed air contamination can compromise flight safety.

The recommendations in this document take into account that the fluids used in aviation (including jet engine oils) and their pyrolysis products are complex mixtures. Some of these mixtures contain organophosphates, ultra-fine particles, and other chemical compounds.

The recommendations in the document take into account current and developing legal frameworks in order to enable the industry to meet their legal obligation to provide a safe environment for air crew and passengers. This document also acknowledges, at the European Commission level, the value of using the Precautionary Principle in relation to risk management, and the use of risk assessment in this industry to protect workers and the environment.

Within this document, emphasis is placed upon exposure prevention, sensor technology, worker training, reporting systems, and collation of data and information from air crew and passengers. Safety Management Systems (SMS) can be a useful tool to enable operators to apply these measures to monitor and respond to system degradation.

This document does not define acceptability/suitability for health, comfort, safety, or airworthiness of the cabin air.

Annex I contains a summary of maximum levels of the marker compounds listed in Annex B that have been published.

1 Scope

This document defines recommendations dealing with the quality of the air on civil aircraft concerning chemical compounds potentially originating from, but not limited, to, the ventilation air supplied to the cabin and flight deck.

A special emphasis is on the engine and APU bleed air contaminants potentially brought into the cabin through the air conditioning, pressurization and ventilation systems.

This document is applicable to civil aircraft in operation from the period that is defined as when the first person enters the aircraft until the last person leaves the aircraft.

This document recommends means to prevent exposure to certain type of chemical compounds, including those that could cause adverse effects, taking into account the Precautionary Principle.

2 Normative references

There are no normative references in this document.

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:

- ISO Online browsing platform: available at http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
adverse effect
change in morphology, physiology, growth, development or lifespan of an organism which results in impairment of its functional capacity or impairment of its capacity to compensate for additional stress or increased susceptibility to the harmful effects of other environmental influences

[SOURCE: ISO 13073-3:2016, 2.1]

3.2
aerosol
system of solid particles and/or liquid droplets suspended in gas

3.3
air crew
people working on an aircraft in the period that is defined as when the first person boards the aircraft until the last person leaves the aircraft, including pilots and cabin crew

3.4
airline operator
entity authorized by an Air carrier Operator Certificate (AOC) from its national Civil Aviation Authority to operate civil transport aircraft flights for commercial carriage of passengers, cargo or mail

Note 1 to entry: The airline operator holds responsibility for compliance with civil aviation authority regulations on its flights, including when the relevant tasks are performed by sub-contractors.

[SOURCE: ISO 16412:2005, 3.3, modified — The terms originally defined were “operator”, “airline” and “carrier”.][2]

3.5
auxiliary power unit
APU
gas turbine-powered unit delivering rotating shaft power, compressor air, or both, which is not intended for direct propulsion of an aircraft

[SOURCE: EASA CS Definitions] [3]

3.6
best available technology
BAT
most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular technologies for providing, in principle, the basis to mitigate, or eliminate exposure to contaminants in cabin air

[SOURCE: Council Directive 2008/1/EC, modified] [4]

3.7
bleed air
air bled off the compressor stages of the aircraft engines or APU, prior to the combustion chamber; source of ventilation air

3.8
cabin air
air within the section of an aircraft in which passengers and/or air crew travel (including the cabin and flight deck)

3.9
cabin material
cabin interior which includes seats, flooring, walls, cabinets and overhead bins

3.10
chemical compound
chemical element or compound on its own or admixed as it occurs in the natural state or as produced, used, or released, including release as waste, by any work activity, whether or not produced intentionally and whether or not placed on the market

[SOURCE: Council Directive 98/24/EC Art. 2(a)][5]

3.11
contaminant
substance emitted into the air adversely affecting air quality

[SOURCE: ISO 4225:2020] [6]

3.12
early warning system
system or a procedure to detect the presence of contaminants that may require intervention

3.13
electrical-environmental control system
E-ECS
bleed-free ECS

3.14
environment control system
ECS
system of an aircraft which provides ventilation supply air, temperature control, and cabin pressurization for the crew and passengers

3.15
fresh air (see also: outside air)
air taken from outside the vehicle

Note 1 to entry: In this document, the vehicle is the aircraft.

3.16
fumes
odorous, gaseous emission of compound(s) and/or aerosols which may be sourced to the cabin/flight deck ventilation supply air vents and is not visible

3.17
hazardous
substance or mixture fulfilling the criteria relating to physical hazards, health hazards, or environmental hazards

[SOURCE: Regulation (EC) No 1272/2008 "CLP", Article 3] [7]

Note 1 to entry: (i) any chemical agent which meets the criteria for classification as hazardous within any physical and/or health hazard classes laid down in Regulation (EC) No 1272/2008 of the European Parliament and of the Council, whether or not that chemical agent is classified under that Regulation; and(ii) any chemical agent which, whilst not meeting the criteria for classification as hazardous in accordance with point (i) may, because of its physico-chemical, chemical or toxicological properties and the way it is used or is present in the workplace, present a risk to the safety and health of workers, including any chemical agent that is assigned an occupational exposure limit value under Article 3.

[SOURCE: Directive (EC) No 98/24, Article 2]

Note 2 to entry: This definition of hazardous is different to the definition applied in the airworthiness context.

3.18
marker compound
chemical compound representing/indicating specific/potential sources of airborne contaminants in the cabin air

3.19
outside air (see also: fresh air)
air taken from outside the vehicle

[SOURCE: ISO 19659-1:2017, 3.4.1] [8]

Note 1 to entry: In this document, the vehicle is the aircraft.

3.20
real-time sampling
use of online monitoring using instrumental analysers with sensors; the output describes the change in concentration of the analyte(s) as a function of time during the sampling period

3.21
risk analysis
systematic use of available information to identify hazards and to estimate the risk

[SOURCE: ISO/IEC Guide 51:2014, 3.10] [9]

3.22
safety management system
SMS
administrative framework that is designed to manage safety risks in workplaces and is applied to enable the operator to systematically monitor and respond to fume events

3.23
sensor
electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic

[SOURCE: ISO/IEC TR 29181-9:2017,3.14] [10]

3.24
soot
particulate matter with a particle size of 0 nanometres (nm) to 10 nm produced and deposited during or after combustion

[SOURCE: EN ISO 472:2013, 2.1278 modified] [11]

3.25
steady state
condition during single engine power setting characterized by stable temperature and bleed pressure

[SOURCE: SAE (2018)] [12]

3.26
supply air
air introduced into an enclosure by mechanical means including engines, APU, onboard electric compressors, or ground supply units

3.27
time-integrated sampling
either passive or active sampling methodology, followed by analysis of the collected sample in dedicated equipment or a laboratory; the output describes the average concentration of the analyte(s) during the sampling period

3.28
transient operating condition
condition other than steady state engine power setting characterized by unstable temperature and/or changing pressure; examples include engine start, take-off top-of-descent and changes in engine regime including changing the power setting from idle to take off power and back

3.29
ultra-fine particles
ultra-fine particles (UFP) or ultrafine dust are the most commonly used definitions of airborne particles with a diameter between 1 and 100 nanometres (nm)

[SOURCE: ISO 2007] [13]

4 Cabin air quality — chemical compounds

4.1 Chemical compounds in cabin air

The presence and concentration of many chemical compounds have been measured in the cabin air and are reported in numerous studies, providing a large database of chemical compounds. Most of these data were collected in the cabin or flight deck during normal operating conditions and not during a reported "fume event" (see 4.4). Some of these data were collected directly from a bleed air source.

Monitoring the cabin air for the presence of appropriate chemical marker compounds is a method to indicate the source(s) of contamination, rather than to assess any health effects of exposure.

4.2 Sources of chemical compounds

Chemical compounds can be sourced to the outside environment and can also originate from the aircraft itself. These may include, but are not limited to the following:

— engine oil;

— hydraulic fluid;

— engine exhaust;

— fuel (unburned and vapours);

— de-icing fluid;

— chemical products used to wash engines or turbines;

— occupants;

— cabin materials and cleaning products;

— air conditioning equipment; and

— faulty/failed electrical items.

An overview of a subset of the chemical compounds associated with some of these sources that may be introduced to the cabin air is provided in Annex G.

4.3 Sources of engine oil leakage in the bleed air system

The presence of oil fumes in the cabin air can, in some instances, be linked to the oil lubrication system. A description of the oil lubrication system, the seal technology, and possible contamination of the cabin air with engine oil are discussed in Annex H.

4.4 Fume event

A fume event is characterized by the presence of fumes in the cabin, emanating from the ventilation supply air vents which can indicate the presence of a specific contamination of the ventilation supply air (e.g., engine oil, hydraulic fluid, de-icing fluid) that has originated from or entered the engine or APU.

Alternatively, the presence of fumes and/or aerosols in cabin may emanate from a source within the cabin (e.g., galley ovens, electrical faults).

4.5 Marker compounds

A subset of marker compounds that can be present in cabin air is listed in Annex B, Table B.1. These marker compounds are associated with major contaminant sources from bleed air and outside air. They are deemed to be useful markers for these specific sources of air contamination in the aircraft environment.

Table B.2 lists "reliability ratings" (A through C) for each marker compound, intended to assist the reader in determining which combination of compounds to monitor for each source of contamination listed in 4.2.

Annex I lists published studies that, together, include measurement data for 14 of the 16 marker compounds in Annex B. The maximum value of each measured compound was commonly reported so is provided in Table I.1 for comparison purposes.

4.6 Environmental control systems (ECS)

The purpose of the ECS is to provide ventilation supply air and regulate the aircraft cabin pressure and temperature in order to provide a safe and comfortable environment for the passengers and crew.

Most commercial passenger aircraft are equipped with an ECS that processes bleed air from engine compressors, whilst some ECS process air from electrical compressors. Airborne chemical compounds can be introduced into the cabin air through the aircraft ventilation supply air system. Further details on these two types of ECS are provided in Annex A.

5 Precautionary Principle and hierarchy of controls

5.1 General

Airborne chemical agents can be sourced to the ventilation supply air (e.g., engine oil, hydraulic fluid, de-icing fluid, and exhaust fumes) and the aircraft cabin surfaces, equipment, and occupants (see Clause 4). Exposure to these chemical agents can be prevented/minimized through the application of the design and maintenance measures in this document, all of which should be planned and implemented according to the Precautionary Principle (see 5.2) and the hierarchy of controls (see 5.3).

The objective of these design and maintenance measures is to prevent/minimize onboard exposure to airborne contaminants, with a special emphasis on the ventilation supply air. This can be accomplished by:

a) implementing an onboard monitoring system that gives, at the earliest possible time, an indication of a system degradation or change in the cabin air quality (see Clause 7). This allows for appropriate operational and/or maintenance actions intended to enhance flight safety and protect the health of crew and passengers;

b) using portable monitoring equipment (see 7.3) based on the presence of selected chemical marker compounds (see Annex B) as an additional maintenance monitoring and troubleshooting tool; and

c) adopting other design, operational, and maintenance measures (see Clause 8 and Annex F).

The chemical marker compounds listed in Annex B (see Table B.1) are deemed to be the most reliably associated with the primary contaminant sources (see 4.2) and are, thus, an appropriate basis for onboard and portable monitoring equipment (see Clause 7). However, alternative methods could be also applied to indicate the presence of a specific contaminant source (e.g. by pattern recognition; see 7.1 and Annex D).

In addition to these design and maintenance measures, recommended administrative measures (i.e., medical monitoring, standardized reporting, airline worker training/education) are described in Clauses 9, 10 and 11.

Also, examples of "best practice" exposure control measures are described in Annex F, and supplemental information on relevant aircraft systems and contaminant sources is provided in the remaining annexes.

5.2 Precautionary Principle

Airline operators, maintenance organisations and manufacturers should apply the Precautionary Principle while performing a risk assessment to characterize the risks of exposure to the main contamination sources listed in Clause 4.

As a part of this risk assessment for aircraft engines and APUs that supply bleed air, manufacturers should measure engine and APU-generated contaminants over the full range of engine power settings expected to occur in service, including on-wing testing and transient power settings, and should assess the potential for fluid loss during normal operation, as well as accidental leaks, spillage, and overfills.

Airline operators should perform a risk assessment on cabin air contamination, including risks that cannot be avoided. For most carcinogens and mutagens, it is not feasible to identify levels below which exposure cannot lead to adverse effects.

Based on these risk assessments, airline operators, maintenance organisations, and manufacturers should apply the Precautionary Principle and the hierarchy of controls (see 5.3) to mitigate the risks of onboard exposure to airborne contaminants. This should include designing systems to minimize fluid emissions during the full range of normal operations.

For additional information on the Precautionary Principle, see Annex C.

5.3 Hierarchy of controls

Airline operators, maintenance organisations and manufacturers should apply the hierarchy of controls to prevent occupant exposure to airborne chemical agents, as follows:

— avoid risks;

— evaluate risks that cannot be avoided;

— control risks at the source;

— eliminate or reduce hazardous chemical exposures by the design and organization of system;

— adapt to technical progress;

— replace the dangerous by the non-dangerous, less dangerous, or safe;

— develop a coherent overall prevention policy which covers technology, organization of work, working conditions, and the influence of factors related to the working environment;

— give appropriate instructions to the workers; and

— give collective protective measures priority over individual protective measures.