



**International
Standard**

**Refrigerants — Designation and
safety classification**

Fluides frigorigènes — Désignation et classification de sécurité

ISO 817

**Fourth edition
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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 document 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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 86, *Refrigeration and air-conditioning*, Subcommittee SC 8, *Refrigerants and refrigeration lubricants*.

This fourth edition cancels and replaces the third edition (ISO 817:2014), which has been technically revised. It also incorporates the Amendments ISO 817:2014/Amd 1:2017 and ISO 817:2014/Amd 2:2021.

The main changes are as follows:

- the scope has been expanded to include data necessary for safe applications of the refrigerants;
- the rules of toxicity safety classification to consider acute and chronic toxicity, have been incorporated into [6.1.2](#);
- requirements to apply for designations, safety classifications, and refrigerant concentration limits for refrigerants, including blends, and requirements to submit new or revised data for refrigerants listed in ISO 817 tables, previously located in Annex F, have been relocated to <https://standards.iso.org/iso/817/ma/en/>.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Refrigerants — Designation and safety classification

1 Scope

This document provides an unambiguous system for assigning designations to refrigerants. It also establishes a system for assigning a safety classification to refrigerants based on toxicity and flammability data, and provides a means of determining the refrigerant concentration limit. Tables listing the refrigerant designations, safety classifications, refrigerant concentration limits and data necessary for safe use of the refrigerants are included based on data submitted with the application.

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/PAS 24499, *Method of test for burning velocity measurement of A2L flammable gases*

ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants*

ASTM D8211, *Standard Test Method for Hot Surface Ignition Temperature of Gases on Flat Surface*

ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapours and Gases)*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

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

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

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

3.1.1

acute toxicity

adverse health effect(s) from a single, short-term exposure

3.1.2

acute-toxicity exposure limit

ATEL

maximum recommended *refrigerant* (3.1.37) concentration determined in accordance with the established systems and intended to reduce the risks of *acute toxicity* (3.1.1) hazards to humans in the event of a *refrigerant* release

Note 1 to entry: The systems are specified in this document.

3.1.3

anaesthetic effect

impairment of the ability to perceive pain and other sensory stimulation

3.1.4
approximate lethal concentration
ALC

concentration of a *refrigerant* (3.1.37) that is lethal to even a single test animal but to less than 50 % of the animals in that group when tested by the same conditions as for an LC₅₀ test

3.1.5
auto-ignition temperature
AIT

lowest temperature at or above which a substance can spontaneously ignite in air at standard atmospheric pressure without an external source of ignition, such as a flame or spark

3.1.6
azeotrope

blend (3.1.7) composed of two or more *refrigerants* (3.1.37) whose equilibrium vapour and liquid phase compositions are the same at a specific pressure, but can be different at other conditions

3.1.7
blend

mixture composed of two or more *refrigerants* (3.1.37)

3.1.8
burning velocity

S_u
velocity, relative to the unburnt gas, at which a laminar flame propagates in a direction normal to the flame front, at the concentration of *refrigerant* (3.1.37) with air giving the maximum velocity

Note 1 to entry: This value is expressed in centimetres per second.

3.1.9
central nervous system effect
CNS

treatment-related depression, distraction, stimulation, or other behavioural modification to a degree that could represent an impairment of the ability to escape from a hazard

3.1.10
chronic toxicity

adverse health effect(s) from long-term repeated exposures

3.1.11
combustion

exothermal reaction between an oxidant component (combustive) and a reducer (combustible fuel)

3.1.12
compound

substance composed of two or more atoms chemically bonded in definite proportions

3.1.13
critical point

point with conditions above which distinct liquid and gas phases do not exist

3.1.14
cyclic compound

organic compound whose structure is characterized by a closed ring of atoms

3.1.15
effective concentration 50 %

EC₅₀
concentration of a *refrigerant* (3.1.37) which causes a biological effect to 50 % of exposed animals in a test for anaesthetic or other effects

Note 1 to entry: This value is typically a calculated value from experimental data.

3.1.16

elevated temperature flame limit

ETFL

minimum concentration by volumic ratio (volume per cent) of the *refrigerant* (3.1.37), which is capable of propagating a *flame* (3.1.18) through a homogeneous mixture of the *refrigerant* and air under the specified test conditions at 60,0 °C and 101,3 kPa

Note 1 to entry: The test conditions are specified in 6.1.3.

Note 2 to entry: 101,3 kPa is the standard atmospheric pressure at sea level.

3.1.17

equivalence ratio

fraction of the combustible in the mixture divided by the combustible fraction at the stoichiometric conditions

Note 1 to entry: It can be written as (combustible fraction)/(combustible fraction)_{st}.

Note 2 to entry: It is used in the determination of *burning velocity* (3.1.8).

Note 3 to entry: Lean mixtures have an equivalence ratio lower than one and rich mixtures have an equivalence ratio greater than one.

3.1.18

flame

collection of gases of a rapid combustion, generally visible due to the emission of light

3.1.19

flame propagation

combustion, causing a continuous *flame* (3.1.18) which moves upward and outward from the point of ignition without help from the ignition source

Note 1 to entry: Flame propagation as applied in the test method for determining LFL and flammability classification is specified in B.1.8. Flame propagation as applied in the test method for determining *burning velocity* (3.1.8) is described in ISO/PAS 24499.

3.1.20

flame propagation velocity

velocity at which a *flame* (3.1.18) propagates in a space

3.1.21

flammable

property of a mixture in which a *flame* (3.1.18) is capable of self-propagating for a certain distance

3.1.22

fractionation

change in composition of a *blend* (3.1.7) by preferential evaporation of the more volatile component(s) or condensation of the less volatile component(s)

3.1.23

heat of combustion

HOC

heat evolved from a specified exothermic reaction of a substance with oxygen.

Note 1 to entry: The heat of combustion is as determined in accordance with 6.1.3.7.

Note 2 to entry: The heat of combustion for this document is expressed as a positive value for exothermic reactions in energy per unit mass (kJ/kg).

Note 3 to entry: The heat of combustion for Class 2L, 2, and 3 *refrigerants* (3.1.37) is listed in Tables E.2 and E.3 available at <https://standards.iso.org/iso/817/ma/en>.

3.1.24

hot surface ignition temperature

HSIT

lowest temperature at which a substance ignites in normal atmosphere when impinged upon a heated surface

Note 1 to entry: Refer to ASTM D8211.

3.1.25

immediately dangerous to life or health

IDLH

atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere

Note 1 to entry: IDLH values are used by the National Institute for Occupational Safety and Health (NIOSH) as respirator selection criteria.

3.1.26

isomer

two or more compounds having the same chemical composition with differing molecular configurations

3.1.27

lethal concentration 50 %

LC₅₀

atmospheric concentration that is lethal to 50 % of the exposed population

Note 1 to entry: LC₅₀ is associated with inhalation exposures.

3.1.28

lethal dose 50 %

LD₅₀

oral or dermal dose that is lethal to 50 % of the exposed population

3.1.29

lower flammability limit

LFL

minimum concentration of the *refrigerant* (3.1.37) that is capable of propagating a *flame* (3.1.18) through a homogeneous mixture of the *refrigerant* and air under the specified test conditions at 23,0 °C and 101,3 kPa

Note 1 to entry: The test conditions are specified in 6.1.3.

Note 2 to entry: The LFL is expressed as *refrigerant* percentage by volume.

3.1.30

lowest observed adverse effect level

LOAEL

lowest concentration of a *refrigerant* (3.1.37) that causes any observed adverse effect on one or more test animals

3.1.31

no observed adverse effect level

NOAEL

highest concentration of a *refrigerant* (3.1.37) at which no adverse effect is observed on even one test animal.

3.1.32

nominal composition

nominal formulation

design composition as stated in the *refrigerant blend* (3.1.7) application, excluding any tolerances

Note 1 to entry: Composition of the *refrigerant blends* shall be as listed in Tables C.2 and C.3.

Note 2 to entry: When a container with the nominal composition is 80 % or more liquid filled, the liquid composition can be considered the nominal composition.

3.1.33

occupational exposure limit

OEL

time-weighted average concentration for a normal 8 h workday and a 40 h work week to which nearly all workers can be repeatedly exposed without adverse effect

Note 1 to entry: The OEL is determined by an independent organization that (1) is composed of health science experts, (2) is experienced in generating OELs for *refrigerant* compounds and (3) formally publishes the derived OELs in a way that is publicly accessible.

3.1.34

olefin

unsaturated chemical compound containing at least one carbon-to-carbon double bond

3.1.35

oxygen deprivation limit

ODL

concentration of a *refrigerant* (3.1.37) or other gas that can result in insufficient oxygen for normal breathing

3.1.36

quenching

effect of extinction of a *flame* (3.1.18) as it approaches a surface due to heat conduction losses, absorption of active chemical species and viscous effects on the surface

3.1.37

refrigerant

fluid used for heat transfer in a refrigerating system

Note 1 to entry: A refrigerant absorbs heat at a low temperature and a low pressure of the fluid and rejects it at a higher temperature and a higher pressure of the fluid, usually involving changes of the phase of the fluid.

3.1.38

relative molar mass

mass numerically equal to the molecular mass expressed in grams per mole, except that it is dimensionless

3.1.39

saturated organic compound

carbon-containing compound that has only single bonds between carbon atoms

3.1.40

stoichiometric concentration for combustion

C_{st}

concentration of a fuel in a fuel-air mixture that contains exactly the necessary quantity of air (21 % O₂/79 % N₂ by volume) needed for the complete oxidation of all compounds present

3.1.41

threshold limit value-short term exposure limit

TLV-STEL

15 min time weighted average exposure that should not be exceeded at any time during a workday

3.1.42

threshold limit value-time weighted average

TLV-TWA

time weighted average concentration for a normal 8 h workday and a 40 h work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect

3.1.43

unsaturated organic compound

carbon-containing compound containing at least one double or triple bond between carbon atoms

3.1.44

workplace environmental exposure limit

WEEL

occupational exposure limit (3.1.33) set by the Toxicology Excellence for Risk Assessment (TERA)

3.1.45

worst-case formulation

WCF

composition that results from application of the tolerances to the *nominal composition* (3.1.32) resulting in the most toxic or the most *flammable* (3.1.21) formulation

3.1.46

worst-case fractionated formulation

WCFF

composition produced during *fractionation* (3.1.22) of the *worst-case formulation* (3.1.45) that results in the most toxic or most *flammable* (3.1.21) formulation

3.1.47

zeotrope

blend (3.1.7) composed of two or more *refrigerants* (3.1.37) whose equilibrium vapour and liquid phase compositions are not the same at any pressure below the critical pressure

3.2 Abbreviated terms

ACGIH	American Conference of Governmental Industrial Hygienists
AIT	auto-ignition temperature
ALC	approximate lethal concentration
ATEL	acute-toxicity exposure limit
CNS	central nervous system effect
C_{st}	stoichiometric concentration for combustion
EC ₅₀	effective concentration 50 %
ETFL	elevated temperature flame limit
HOC	heat of combustion
HSIT	hot surface ignition temperature
IDLH	immediately dangerous to life or health
LC ₅₀	lethal concentration 50 %
LD ₅₀	lethal dose 50 %
LFL	lower flammability limit
LOAEL	lowest observed adverse effect level
NIOSH	National Institute for Occupational Safety and Health (United States)
NOAEL	no observed adverse effect level
ODL	oxygen deprivation limit
PEL	permissible exposure limit

ppm	parts per million
TCF	toxic concentration factor
TLV-STEL	threshold limit value short-term exposure limit
TLV-TWA	threshold limit value-time weighted average
WCF	worst-case formulation
WCFF	worst-case fractionated formulation
WEEL	workplace environmental exposure limit

3.3 Symbols

a_{blend}	mortality indicator for a refrigerant blend
a_n	mortality indicator for component n in a refrigerant blend
a_f	cross-sectional area of the flame base
A_f	flame surface area
b_n	cardiac sensitization indicator for component n in a refrigerant blend
b_{blend}	anaesthetic effect indicator for a refrigerant blend
c_n	anaesthetic effect indicator for component n in a refrigerant blend
c_{blend}	anaesthetic effect indicator of a refrigerant blend
C_{blend}	toxic concentration factor of a refrigerant blend
C_n	toxic concentration factor for component n
C_{st}	stoichiometric concentration for combustion
S_s	flame propagation speed, expressed in cm/s
S_u	burning velocity, expressed in cm/s
x_n	mole fraction of component n of a refrigerant blend
Φ_{max}	equivalence ratio at the maximum burning velocity

4 Numbering of refrigerants

4.1 Refrigerant Tables

An identifying number shall be assigned to each refrigerant. Assigned numbers and safety classifications are shown in Tables C.1, C.2 and C.3. Tables E.4, E.5 and E.6 provide designations for refrigerants for which insufficient data are available for safety classification or determination of refrigerant concentration limits.

NOTE 1 Tables C.1, C.2, C.3, E.1, E.2, E.3, E.4, E.5, and E.6 are available at: <https://standards.iso.org/iso/817/ma/en>.

NOTE 2 Requirements to apply for designations, safety classifications, and refrigerant concentration limits for refrigerants, including blends, and requirements to submit new or revised data for refrigerants are provided at <https://standards.iso.org/iso/817/ma/en/>.

NOTE 3 The name and contact information of the maintenance agency for this document can be found at www.iso.org/maintenance_agencies.

4.2 Identifying numbers

4.2.1 General

The identifying numbers assigned to the hydrocarbons, halocarbons and ethers of the methane, ethane, ethene, propane, propene, butane, butene, cyclobutene and cyclobutane series are such that the chemical composition of the compounds can be explicitly determined from the refrigerant numbers, and vice versa, without ambiguity. The molecular structure can be similarly determined for the methane, ethane, ethene and most of the propane and propene series from only the identification number.

4.2.2 First digit on the right

The first digit on the right is the number of fluorine (F) atoms in the compound.

4.2.3 Second digit from the right

The second digit from the right is one more than the number of hydrogen (H) atoms in the compound.

4.2.4 Third digit from the right

The third digit from the right is one less than the number of carbon (C) atoms in the compound. When this digit is zero, it is omitted from the number.

4.2.5 Fourth digit from the right

The fourth digit from the right is equal to the number of carbon-carbon double bonds in the compound. When this digit is zero, it is omitted from the number.

4.2.6 Presence of bromine (Br) or iodine (I)

In those instances where bromine (Br) or iodine (I) is present the same rules apply, except that the upper-case letter B or I after the designation determined according to 4.2.2 to 4.2.5 shows the presence of bromine or iodine. The number following the letter B or I shows the number of bromine or iodine atoms present.

4.2.7 Number of chlorine (Cl) atoms

The number of chlorine (Cl) atoms in the compound is found by subtracting the sum of fluorine (F), bromine (Br), iodine (I) and hydrogen (H) atoms from the total number of atoms that can be connected to the carbon (C) atoms. For saturated organic compounds, this number is $2n + 2$, where n is the number of carbon atoms. The number is $2n$ for compounds with one double bond and saturated cyclic compounds.

4.2.8 Carbon atoms

The carbon atoms shall be numbered with the number 1 assigned to the end carbon with the greatest number of halogen atoms, and the following carbon atoms are numbered sequentially as they appear on a straight chain. In the case where both end carbons contain the same number of (but different) halogen atoms, the number 1 shall be assigned to the end carbon having the largest number of bromine then chlorine then fluorine, and then iodine atoms. If the compound is an olefin (i.e., unsaturated organic compound), then the end carbon nearest to the double bond will be assigned the number 1, as the presence of a double bond in the back bone of the molecule has priority over substituent groups on the molecule.

4.2.9 Cyclic compounds

For cyclic compounds, the letter C is used before the identifying refrigerant numbers. (e.g. R-C318, PFC-C318).

4.2.10 Isomers in the ethane and ethene series

In the case of isomers in the ethane and ethene series, each shall have the same number, with the most symmetrical one indicated by the number alone. As the isomers become more and more unsymmetrical, successive lower-case letters (e.g. a, b, or c) are appended. Symmetry is determined by first summing the atomic mass of the halogen and hydrogen atoms attached to each carbon atom. One sum is subtracted from the other; the smaller the absolute value of the difference, the more symmetrical the isomer.

4.2.11 Isomers in the propane series

In the case of isomers in the propane series, each shall have the same number, and the isomers shall be distinguished by two appended lower-case letters. The first appended letter indicates the substitution on the central carbon atom (C2) as indicated in [Table 1](#).

Table 1 — Propane isomer appended letters

Isomer	Appended letter
CCl ₂	a
CClF	b
CF ₂	c
CHCl	d
CHF	e
CH ₂	f

For halogenated derivatives of cyclopropane, the carbon atom with the largest sum of attached atomic masses shall be considered the central carbon atom; for these compounds, the first appended letter is omitted. The second appended letter indicates the relative symmetry of the substituents on the end carbon atoms (C1 and C3). Symmetry is determined by first summing the atomic masses of the halogen and hydrogen atoms attached to the C1 and C3 carbon atoms. One sum is subtracted from the other; the smaller the absolute value of this difference, the more symmetrical the isomer. In contrast to the ethane series, however, the most symmetrical isomer has a second appended letter of a (as opposed to no appended letter for ethane isomers); increasingly asymmetrical isomers are assigned successive letters. Appended letters are omitted when no isomers are possible, and the number alone represents the molecular structure unequivocally; for example, CF₃CF₂CF₃ is designated R-218, not R218ca. An example of this system is given in [Annex A](#).

4.2.12 Isomers in the propene series

In the case of isomers in the propene series, each has the same number, with the isomers distinguished by two appended lower-case letters. The first appended letter designates the one atom attached to the central carbon atom and shall be x, y, or z for Cl, F, and H, respectively. The second letter designates the substitution on the terminal methylene carbon as indicated in [Table 2](#).

Table 2 — Propene isomer appended letters

Isomer	Appended letter
CCl ₂	a
CClF	b
CF ₂	c
CHCl	d
CHF	e
CH ₂	f

4.2.13 Extension to compounds of four carbon atoms

Compounds are coded according to the above stated rules, with the designation number followed by a set of letters indicating structure. The number of unsaturated linkages is given in the fourth digit from the right. When the number for a digit place exceeds nine, it is set off by dashes.

Linear compounds are lettered starting at one end, cyclic compounds from a side group, or, if none, from a carbon in the ring as described in 4.2.11. Carbon atoms with two hydrogens or halogens are lettered as in 4.2.11. Carbon atoms with three hydrogen or halogen atom substituents are lettered as indicated in Table 3:

Table 3 — Butane isomer appended letters

Isomer	Appended letter
-CCl ₃	j
-CCl ₂ F	k
-CClF ₂	l
-CF ₃	m
-CHCl ₂	n
-CH ₂ Cl	o
-CHF ₂	p
-CH ₂ F	q
-CHClF	r
-CH ₃	s

Only as many letters are used as are required to completely define the compound when taken with the empirical structure given by the numerical designation. It is understood that no branching occurs in the remaining structure. After the starting point, side groups are given their letters before the back bone substituent (if any). When two or more lettering sequences may be applied, that with the fewest letters and first alphabetical sequence is used.

4.2.14 Identification of stereoisomers

In the case where stereoisomers can exist, the opposed (Entgegen) isomer will be identified by the suffix (E) and the same side (Zusammen) isomer will be identified by the suffix (Z).

NOTE See Table A.3 for an example of this system.

4.3 Ether-based refrigerants

4.3.1 General

Ether-based refrigerants shall be designated with the prefix “E” (for “ethers”) immediately preceding the number. 4.2 applies except for the following differences.

4.3.2 Two-carbon, dimethyl ethers

Two-carbon, dimethyl ethers (e.g. R-E125, CHF₂-O-CF₃) require no suffixes other than those specified in 4.2.10, as the presence of the “E” prefix provides an unambiguous description.

4.3.3 Straight chain, three carbon ethers

4.3.3.1 General

For straight chain, three carbon ethers, the carbon atoms shall be numbered with the number 1 assigned to the end carbon with the highest number of halogens, and the following carbon atoms are numbered sequentially as they appear on a straight chain. In the case where both end carbons contain the same number of (but different)

halogen atoms, the number 1 shall be assigned to the end carbon having the largest number of bromine, then chlorine, then fluorine and then iodine atoms. For ethers with more than three carbons, the compound shall be assigned a number in the 600 series, miscellaneous organic compounds, as described in [4.5](#).

4.3.3.2 Identifying the first carbon to which the ether oxygen is attached

An additional integer identifying the first carbon to which the ether oxygen is attached shall be appended to the suffix letters (e.g. R-E236ea2, CHF₂-O-CHF-CF₃).

4.3.3.3 Symmetric hydrocarbon structures

In the case of otherwise symmetric hydrocarbon structures, the ether oxygen shall be assigned to the carbon which has the leading position in the formula.

4.3.3.4 Only a single isomer exists

In those cases where only a single isomer exists for the hydrocarbon portion of the ether structure, such as CF₃-O-CF₂-CF₃, the suffix letters described in [4.2.10](#), [4.2.11](#) and [4.2.13](#) shall be omitted. In this cited example, the correct designation shall be R-E218.

4.3.3.5 Structures containing two oxygen atoms, di-ethers

Structures containing two oxygen atoms, di-ethers, shall be designated with two suffix integers to designate the positions of the ether oxygen atoms.

4.3.4 Cyclic ethers

For cyclic ethers carrying both the "C" and "E" pre-fixes, the "C" shall precede the "E," as "CE," to designate "cyclic ethers." For four-membered cyclic ethers, including three carbon and one ether oxygen atom, the basic number designations for the hydrocarbon atoms shall be constructed according to the current standard for hydrocarbon nomenclature, as described in [4.2](#).

4.4 Blends

4.4.1 General

Blends are assigned a refrigerant number in the 400, 500, or 4000 series.

4.4.2 Zeotropes

Zeotropes shall be assigned an identifying number in the 400 or 4000 series. In order to differentiate among the different zeotropes having the same components but in different proportions, an upper-case letter (A, B, C, etc.) is added after the number.

NOTE Refrigerants in the R-4000 series start with R-4101A to avoid confusion with other common 400 series refrigerants.

4.4.3 Azeotropes

Azeotropes shall be assigned an identifying number in the 500 series. In order to differentiate among the different azeotropes having the same components but in different proportions, an upper-case letter (A, B, C, etc.) is added after the number.

4.4.4 Blend tolerances

Blends shall have tolerances specified for individual refrigerants. Those tolerances shall be specified to the nearest 0,1 % mass fraction. The maximum tolerance above or below the nominal composition shall not exceed 2,0 % mass fraction.

The minimum tolerance above or below the nominal shall be as follows:

- a) 0,1 % m/m for component, x , with concentration: $0,6 \% \leq x \leq 16,6 \%$ or $83,4 \% \leq x \leq 99,4 \%$
- b) 0,2 % m/m for component, x , with concentration: $16,7 \% \leq x \leq 33,3 \%$ or $66,7 \% \leq x \leq 83,3 \%$
- c) 0,3 % m/m for component, x , with concentration: $33,4 \% \leq x \leq 66,6 \%$

The difference between the highest and the lowest tolerances shall not exceed one-half of the nominal component composition. No component shall be permitted at less than 0,6 % m/m nominal.

NOTE Refer to [Annex F](#) for examples of minimum composition tolerances.

4.4.5 Composition uniqueness

To ensure composition uniqueness, blends with the same components shall have at least one component range, including tolerances, that does not overlap and is separated by a minimum of 0,1 % m/m.

4.5 Miscellaneous organic compounds

Miscellaneous organic compounds shall be assigned numbers in the 600 series in decadal groups, as outlined in Table E.4, in serial order of designation within the groups. For the saturated hydrocarbons with 4 to 8 carbon atoms, the number assigned shall be 600 plus the number of carbon atoms minus 4.

EXAMPLE 1 Butane is R-600, pentane is R-601, hexane is R-602, heptane is R-603, and octane is R-604.

The straight chain or “normal” hydrocarbon has no suffix. For isomers of the hydrocarbons with 4 to 8 carbon atoms, the lower-case letters “a”, “b”, “c”, etc., are appended to isomers according to the group(s) attached to the longest carbon chain as indicated in [Table 4](#).

EXAMPLE 2 R-601a is assigned for 2-methylbutane (isopentane) and R-601b would be assigned for 2,2-dimethylpropane (neopentane). Mixed isomers where the concentration of one isomer is greater than or equal to 4 % shall be assigned a number in the 400, 500, or 4000 series.

Table 4 — Miscellaneous organic compound suffixes

Attached group	Suffix
none (straight chain)	No suffix
2-methyl-	a
2,2-dimethyl-	b
3-methyl-	c
2,3-dimethyl-	d
3,3-dimethyl-	e
2,4-dimethyl-	f
2,2,3-trimethyl-	g
3-ethyl-	h
4-methyl-	i
2,5-dimethyl-	j
3,4-dimethyl-	k
2,2,4-trimethyl-	l
2,3,3-trimethyl-	m
2,3,4-trimethyl-	n
2,2,3,3-tetramethyl-	o
3-ethyl-2-methyl-	p
3-ethyl-3-methyl-	q

4.6 Inorganic compounds

4.6.1 General

Inorganic compounds shall be assigned identifying numbers in the 700 series and 7000 series.

4.6.2 Compounds with relative molar masses less than 100

For compounds with relative molar masses less than 100, the number shall be the sum of 700 and the relative molar mass, rounded to the nearest integer.

4.6.3 Compounds with relative molar masses equal to or greater than 100

For compounds with relative molar masses equal to or greater than 100, the identifying number shall be the sum of 7 000 and the relative molar mass rounded to the nearest integer.

4.6.4 Two or more inorganic refrigerants with the same molar masses

When two or more inorganic refrigerants have the same molar masses, upper-case letters (i.e. A, B, C, etc.) shall be added in serial order of designation to distinguish among them starting with the letter A for the second identified inorganic refrigerant of the given molar mass.

5 Designation prefixes

5.1 General prefixes

The identifying number, as determined by [Clause 4](#), shall be preceded by the letter R or the word Refrigerant(s) unless composition designating prefixes as described in [5.2](#) are being used. Between the letter R or the word Refrigerant and the designation number, no space, a blank or a dash is used. Examples include: R134a, Refrigerant 134a, R 134a, and R-134a.

5.2 Composition-designating prefixes

For the fluorocarbon and the hydrocarbon families, the identifying number, as determined by [Clause 4](#), may be prefixed by a letter sequence which designates the elements which constitute the specific compound. The composition-designating prefix shall consist of the first letter of elements contained in the compound. The first element listed shall be H for hydrogen if present and the last shall be C for carbon. The intermediate letters shall represent the halogens listed in the following order: I for iodine, B for bromine, C for chlorine and F for fluorine.

NOTE 1 Halogenated compounds that contain hydrogen have increased deterioration potential before reaching the stratosphere.

The compositional designating prefixes for ethers shall substitute an "E" for "C" (carbon), such that HFE, HCFE, and CFE refer to hydrofluoroether, hydrochlorofluoroether, and chlorofluoroether, respectively. E in the identifying number shall be omitted when composition-designating prefixes are used. The composition designating prefixes for halogenated olefins shall be either

- CFC, HCFC, HCC, or HFC to refer to chlorofluorocarbon, hydrochlorofluorocarbon, hydrochlorocarbon, or hydrofluorocarbon, respectively; or
- with substitution of an O for the carbon C as CFO, HCFO, HCO or HFO to refer to chlorofluoro-olefin, hydrochlorofluoro-olefin, hydrochloro-olefin or hydrofluoro-olefin, respectively.

NOTE 2 Halogenated olefins are a subset of halogenated organic [or carbon containing] compounds having significantly shorter atmospheric lifetimes than their saturated counterparts.

In addition, when a refrigerant compound is fully fluorinated the notation PFC is used. Examples are shown in [Table 5](#).

Table 5 — Examples of composition-designating prefixes

Refrigerant	Composition	Prefix and designation
Chlorofluorocarbon 12	CCl_2F_2	CFC-12
Hydrochlorofluorocarbon 22	CHClF_2	HCFC-22
Hydrofluorocarbon 134a	CH_2FCF_3	HFC-134a
Perfluorocarbon 116	CF_3CF_3	PFC-116
Hydrocarbon 600a	$(\text{CH}_3)_2\text{CH CH}_3$	HC-600a
Perfluorocarbon C318	$-(\text{CF}_2)_4-$	PFC-C318
Hydrofluoroether E125	CHF_2OCF_3	HFE-125
Hydrofluoro-olefin 1234yf	$\text{CF}_3\text{CF}=\text{CH}_2$	HFO-1234yf

Blends with assigned numbers may be identified by linking the appropriate composition-designating prefixes of individual components (e.g. R-500 [CFC-12/HFC-152a]). Blend components shall be listed in order of increasing normal boiling point. Blends without assigned numbers can be identified using appropriate composition-designating prefixes for each component (e.g. HCFC-22/HFC-152a/CFC-114 [36,0/24,0/40,0]). Here [36,0/24,0/40,0] represents the mass fraction of each component, expressed as a percentage.

6 Safety classifications

6.1 General

6.1.1 Safety classification — Composition

The safety classification shall consist of two alphanumeric characters (e.g. A2 or B1) with a third character L designating low burning velocity. The capital letter indicates the toxicity as determined by 6.1.2; the Arabic numeral denotes the flammability as determined by 6.1.3. Blends shall be assigned a flammability classification based on the worst-case fractionated formulation (WCFF), as well as the worst-case formulation (WCF). The WCFF is the more critical but also less commonly occurring value. The toxicity classification of a refrigerant blend is based on the nominal formulation.

6.1.2 Toxicity classification

6.1.2.1 General

Refrigerants shall be assigned to one of two classes, A or B, based on the following:

6.1.2.2 Class A

A refrigerant is assigned toxicity classification A:

- Where the refrigerant or refrigerant blend mortality toxic concentration factor (TCF), as described in 8.1.3, $\geq 2\ 500$ ppm, except when 6.1.2.4 applies, and
- Where the refrigerant or refrigerant blend (1) cardiac sensitization TCF as described in 8.1.4 and (2) the anaesthetic or central nervous system TCF as described in 8.1.5 and (3) other escape impairing and permanent injury TCF as described in 8.1.6 $\geq 10\ 000$ ppm, except when 6.1.2.4 applies, and
- The occupational exposure limit (see 3.1.33) is ≥ 150 ppm.

6.1.2.3 Class B

Where a refrigerant does not comply with 6.1.2.2 for Class A, it shall be assigned toxicity classification B.

6.1.2.4 Exceptions

Non-aromatic flammable hydrocarbon refrigerants with fewer than six carbon atoms are exempt from the acute toxicity criteria.

NOTE Non-aromatic flammable hydrocarbons are known to pose low acute toxicity. Exemptions of these fluids are due to cardiac sensitization, anaesthetic or other escape-impairing symptoms and permanent injury toxic concentration factors being at concentrations higher than the values required for what are considered to be safe (regarding flammability hazards) laboratory practices. Where acute toxicity criteria under [6.1.2.2](#) cannot be met, the safety classification is to be based on the occupational exposure limit (see [3.1.33](#)).

6.1.3 Flammability classification

6.1.3.1 General

Refrigerants shall be assigned to one of four classes (1, 2L, 2 or 3) based on lower flammability limit testing conducted in accordance with ASTM E681 as specified in [Annex B](#), the maximum burning velocity measurement conducted in the method as described hereafter, and the heat of combustion determined in accordance with [6.1.3.7](#). Both lower flammability limit and burning velocity tests shall be conducted at the temperatures and pressures specified below.

Burning velocity measurements shall be conducted according to ISO/PAS 24499 or other credible method. The selected method shall be in agreement with established methods for determining burning velocity by demonstrating to the ISO 817 Maintenance Agency (MA) measurement results of $6,7 \pm 0,7$ cm/s burning velocity for R-32 and $23,0 \pm 2,3$ cm/s for R-152a, or by presenting other evidence supporting the accuracy of the method. Measurement shall be conducted starting from the LFL to at least 125 % of the stoichiometric concentration. Measurements shall be done with increments of at most 10 % of the stoichiometric concentration and each measurement shall be repeated at least two times. The maximum burning velocity is the maximum value obtained from the best curve fitting to the measurement points. The gas mixture shall be made by any method that produces a blend of air/refrigerant that is accurate to $\pm 0,1$ % in the test chamber. Dry air (less than 0,000 15 g of water vapour per gram of dry air) containing $21,0 \pm 0,1$ % O_2 shall be used as oxidant. The flammable gas shall have a minimum purity of 99,5 % mass fraction.

NOTE 1 Methods for burning velocity determination include the vertical tube method and the closed-vessel method.^[1]

NOTE 2 Methods that have been used for mixing include: a) pressurized mixture made using partial pressure, or b) quantitative flow methods like volumetric flow meters and mass flow controllers fixing the ratio of air and refrigerant.

6.1.3.2 Class 1 (no flame propagation)

Single compound refrigerants or refrigerant blends (WCFF) that do not exhibit flame propagation when tested in air at 60 °C and 101,3 kPa.

6.1.3.3 Class 2L (lower flammability)

Single compound refrigerants or refrigerant blends (WCFF) that meet all of the following conditions:

- exhibit flame propagation when tested at 60 °C and 101,3 kPa,
- have a LFL > 3,5 % by volume (see [6.1.3.6](#) if the refrigerant has no LFL at 23 °C and 101,3 kPa.),
- have a heat of combustion < 19 000 kJ/kg (see [6.1.3.7](#)), and
- have a maximum burning velocity of ≤ 10 cm/s when tested at 23 °C and 101,3 kPa.

6.1.3.4 Class 2 (flammable)

Single compound refrigerants or refrigerant blends (WCFF) that meet all of the following conditions:

- exhibit flame propagation when tested at 60 °C and 101,3 kPa,

- b) have an LFL > 3,5 % by volume (see [6.1.3.6](#) if the refrigerant has no LFL at 23 °C and 101,3 kPa.), and
- c) have a heat of combustion < 19 000 kJ/kg (see [6.1.3.7](#)).

6.1.3.5 Class 3 (higher flammability)

Single compound refrigerants or refrigerant blend (WCFF) that meet the following conditions:

- a) exhibit flame propagation when tested at 60 °C and 101,3 kPa and
- b) have a LFL ≤ 3,5 % by volume (see [6.1.3.6](#) if the refrigerant has no LFL at 23 °C and 101,3 kPa.); or have a heat of combustion that is ≥ 19 000 kJ/kg.

6.1.3.6 LFL or ETFL

For Class 2L, 2, or Class 3 refrigerants or refrigerant blends the LFL shall be determined. For those Class 2L, 2, or Class 3 refrigerants or refrigerant blends that show no flame propagation when tested at 23 °C and 101,3 kPa (i.e. no LFL), the elevated temperature flame limit (ETFL) shall be used in lieu of the LFL for determining their flammability classifications.

6.1.3.7 Heat of combustion

6.1.3.7.1 General

The heat of combustion shall be determined at 25 °C and 101,3 kPa as follows.

6.1.3.7.2 Single component refrigerants

For single component refrigerants, the heat of combustion shall be calculated. Values for heats of formation are tabulated in several chemical and physical properties handbooks and databases. The heat of combustion (positive values are exothermic) is the enthalpy of formation of the reactants (refrigerant and oxygen) minus the enthalpy of formation of the products of reaction. Calculated values shall be based on the complete combustion of one mole of refrigerant with enough oxygen for a stoichiometric reaction. The reactants and the combustion products shall be assumed to be in the gas phase. The combustion products shall be HF, CO₂ (N₂, SO₂ if nitrogen or sulphur are part of the refrigerant's molecular structure) and HCl, if there is enough hydrogen in the molecule. Excess H shall be assumed to be converted to H₂O. If there is insufficient hydrogen available for the formation of HF and HCl but sufficient to form HF, then the formation of HF takes preference over the formation of HCl. If there is insufficient hydrogen available for the formation of HF, then the remaining F produces COF₂ in preference to the formation of CO₂. The remaining Cl produces Cl₂.

6.1.3.7.3 Refrigerant blends

For refrigerant blends, the heat of combustion of the nominal composition shall be calculated from a balanced stoichiometric formula of all component refrigerants, where the total number of moles of refrigerant shall be equal to 1.

NOTE This can be thought of conceptually as breaking the refrigerant molecules into their constituent atoms and creating a hypothetical molecule with the same molar ratio of total carbons, hydrogens, fluorines, etc. as in the original blend. The hypothetical molecule would then be treated as a pure refrigerant as in [6.1.3.7.2](#). The heat of formation for this hypothetical molecule is the molar average of the heats of formation for the original blend molecules.

6.2 Matrix diagram of safety group classification system

The toxicity and flammability classifications described in [6.1.2](#) and [6.1.3](#) yield eight separate safety classifications (A1, A2L, A2, A3, B1, B2L, B2, and B3) for refrigerants. These classifications are represented by the matrix shown in [Table 6](#).

Table 6 — Safety groups as determined by flammability and toxicity

	Safety Group	
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1
	Lower toxicity	Higher toxicity

7 Refrigerant classifications and property data

Refrigerant classifications and property data are available in Tables C.1, C.2, and C.3 available at: <https://standards.iso.org/iso/817/ma/en/>.

8 Refrigerant concentration limits

8.1 General

8.1.1 General

Determination of the refrigerant concentration limits shall assume full vaporization and uniform mixing; no removal by dissolution, reaction, or decomposition in the volume to which it is released. Safety factors are included for consideration of temporary local concentrations or uncertainties in the test data.

8.1.2 Acute-toxicity exposure limit (ATEL)

The ATEL shall be the lowest of the toxic concentration factors (TCF) 8.1.3 to 8.1.6. For blends, where available, the blend toxicity data shall be used for the individual parameter values in 8.1.2 to 8.1.6 and when toxicity data for the blends are not available, shall be calculated according to Formula (1):

$$\frac{1}{C_{\text{blend}}} = \frac{x_1}{C_1} + \frac{x_2}{C_2} + \dots + \frac{x_n}{C_n} \quad (1)$$

where

x_n is the mole fraction of component n of the blend;

C_n is the TCF for component n in accordance with ISO 10298.[2]

NOTE See Annex D for a sample calculation of ATEL and Annex E for a list of values related to calculation of refrigerant concentration limits.

8.1.3 Mortality

Value shall be chosen according to the following priority.

First priority: 28,3 % of the 4-h LC₅₀ for rats.

Second priority: 28,3 % of the 4-h ALC for rats provided it did not result in mortality for more than half the exposed animals.

NOTE 28,3 % is based on the recalculation of LC₅₀ for 30 min with a safety factor of 10. The time of 30 min is meant to represent the time required for escape from an area where a refrigerant leak has occurred: $0,283 = (4/0,5)^{1/2}/10$.

Third priority: if neither has been determined, 0 ppm.

[Formula \(2\)](#) and [Formula \(3\)](#) shall be used to adjust LC₅₀ or ALC values that were determined with 15 min to 8 h tests, for refrigerants for which 4 h data are not available:

$$LC_{50(t_1)} = LC_{50(t_2)} \times (t_2 / t_1)^{1/2} \quad (2)$$

and

$$ALC_{t_1} = ALC_{t_2} \times (t_2 / t_1)^{1/2} \quad (3)$$

where

t_1 is 4 h;

t_2 is the test duration, expressed in hours, applicable for 0,25 h to 8 h.

8.1.4 Cardiac sensitization

The cardiac sensitization study is not required in the ATEL determination if the 4-h LC₅₀ or 4-h ALC in [8.1.4](#) is less than 10 000 ppm by volume, or if the refrigerant is found, by toxicological review, to not cause cardiac sensitization.

NOTE 1 Cardiac sensitization is in part a function of attaining a certain minimum blood level of the agent. If the agent is too toxic, one will see other manifestations of toxicity or lethality before cardiac arrhythmias develop.

The value shall be chosen according to the following priority.

First priority: 100 % of the NOAEL for cardiac sensitization in unanaesthetized dogs. If during the cardiac sensitization test other effects cause curtailment of the study prior the determination of a threshold for cardiac sensitization, the highest exposure level tested for which data were collected for at least half of the animals tested may be used as the estimated NOAEL for the cardiac sensitization end point. The conditions where this could occur would be the observance of clinical signs of central nervous system effects or marked signs of systemic toxicity. In these situations the NOAEL for these signs will be lower than the exposure level that resulted in curtailment of the cardiac sensitization study. Therefore the requirement for a determination of the cardiac sensitization evaluation should be considered fulfilled. This NOAEL value should be considered along with the results from all other appropriate studies for the determination of the ATEL.

NOTE 2 This approach is adopted because the emergency of other effects (e.g. tremors or anaesthesia) precludes the ability to determine a cardiac sensitization value.

Second priority: 80 % of the LOAEL provided for the LOAEL did not induce sensitization in more than half the exposed animals.

Third priority: If cardiac sensitization data are not determined, the NOAEL is assigned a value of 1 000 ppm.

8.1.5 Anaesthetic or central nervous system (CNS) effects

The value shall be chosen according to the following priority:

First priority: 50 % of the 10-min EC₅₀, in mice or rats for loss of righting ability in a rotating apparatus.

Second priority: 80 % of NOAEL, in mice or rats for loss of righting ability in a rotating apparatus.

Third priority: 50 % of the LOAEL for signs of any anaesthetic or CNS effect in rats during acute toxicity studies, provided the LOAEL did not induce an anaesthetic effect for more than half the exposed animals.

Fourth priority: 80 % of the NOAEL for signs of anaesthesia or CNS effect in rats during an acute, subchronic, or chronic toxicity study in which clinical signs are documented.

8.1.6 Other escape-impairing symptoms and permanent injury

80 % of the lowest concentration for human exposures of 30 min, that is likely to impair an individual's ability to escape or to cause irreversible, adverse health effects. The source of the value shall be documented.

8.1.7 Oxygen deprivation limit (ODL)

The ODL shall be 140 000 ppm by volume of refrigerant in air (18 % O₂) for locations with altitudes up to and including 1 000 m above sea level. At locations higher than 1 000 m but below or equal to 1 500 m above sea level, the ODL shall be 112 000 ppm, and at altitudes higher than 1 500 m above sea level the ODL shall be 69 100 ppm by volume (19,5 % O₂).

8.2 Data for calculations

8.2.1 Data sources

8.2.1.1 Data for calculations

The data used to calculate the refrigerant concentration limits shall be taken from information in the tables in this standard, if available. If not available in this standard the data shall be taken from peer reviewed scientific publications, published safety assessments by governmental agencies or expert panels or scientific and engineering studies. Applications submitting scientific and engineering studies for toxicity data shall indicate the extent of compliance with good laboratory practices (GLP) in effect when the studies were performed (e.g. Reference [3]), see <https://standards.iso.org/iso/817/ma/en> for application instructions. The information shall be supplied in English. Submissions shall include a description of the experimental and analytical methods used and summarize the qualifications of the person or persons providing the evaluation.

8.2.1.2 Alternative toxicity data

Data from studies which have not been published, from studies which have not been peer reviewed, or from studies involving species other than those indicated in [8.1.2](#), [8.1.3](#), [8.1.4](#), and [8.1.5](#), or involving chemical analogues, may be submitted to the ISO 817 Maintenance Agency (see <https://standards.iso.org/iso/817/ma/en> for application instructions) for consideration. Data are not treated as confidential. Submissions shall include a description of the experimental and analytical methods used, an evaluation of data from alternative sources, and the extent of the data search. The submissions shall summarize the qualifications of the person or persons who conducted the evaluation.

8.2.1.3 Multiple data values

Where multiple data values have been published and submitted to the MA, the MA shall make a judgement as to the values which appear to be the most accurate and realistic. The MA shall keep the record of the logic for the decision.

Exception: For the cardiac sensitization and anaesthetic effect NOAEL in [8.1.4](#) and [8.1.5](#), respectively, the highest-published NOAEL not exceeding a published LOAEL, for any fraction of tested animals, shall be used.

8.2.1.4 Alternative flammability data

Data from studies, which have not been published or from studies which have not been peer reviewed, shall be submitted to the ISO 817 Maintenance Agency for consideration. Submissions shall include a description of the experimental and analytical methods used, and an evaluation of the data from alternative sources, and the extent of the data search. The submissions shall summarize the qualifications of the person or persons who conducted the evaluation. The values used shall be those resulting in the lowest LFL or highest burning velocity when conducted according to the method prescribed in [Clause 6](#).

8.2.2 Consistent measures

Use of data that are determined by the MA to be generated in a manner consistent with those used deriving the data in [8.1.3](#), [8.1.4](#), [8.1.5](#) and [8.1.6](#) is allowed for the parameters identified in [8.1](#).

8.3 Contaminants and impurities

Identify contaminants and impurities, including isomeric and decomposition impurities, from manufacturing, transport, and storage known to increase the flammability or toxicity within the precision of the refrigerant concentration limits. Also identify limits for those impurities.

NOTE AHRI 700^[4] contains a list of common contaminants and information on relevant test methods for determining contaminants.

8.4 Conversion of units — Volumic mass and altitude adjustment

When converting from volumetric ratio (ppm by volume) to volumic mass (g/m³), [Formula \(4\)](#) shall be used. The molecular mass used shall be consistent with the composition used when determining the parameter of interest.

EXAMPLE

- LFL determined at nominal composition will require nominal mass.
- LFL determined at WCF will require WCF molar mass.
- LFL determined at WCFF will require WCFF molar mass.

For blends the molar mass is calculated as a weighted average of the molar mass of the individual components.

[Formula \(4\)](#) uses LFL as an example but is also applicable for ODL and ATEL.

$$f_M = f_{\text{ppm}} \times a \times M \times 10^{-6} \quad (4)$$

where

- f_M is the LFL (g/m³)
- f_{ppm} is the LFL (ppm by volume)
- a is the molar density of the refrigerant (mol/m³)
- M is the relative molar mass of the refrigerant (g/mol)

Molar density is calculated per [Formula \(5\)](#).

$$a = P / RT \quad (5)$$

where

- T is the temperature in Kelvin and equal to 298 in standard calculation;
- P is the pressure in Pascal (pressures shall be adjusted for altitude when greater than 1 500 m above sea level using the following formula: $P = 1,013\,25 \times 10^5 - 10,001 \times h$, where h is the height in metres);
- R equals 8,314 J/mol K.

Updated refrigerant tables are available at: <https://standards.iso.org/iso/817/ma/en>.

Annex A (informative)

Examples of isomer designation

A.1 Ethane series isomers

[Table A.1](#) illustrates the designation of isomers for the ethane series with three isomers of dichlorotrifluoroethane.

Table A.1 — Ethane series isomers

Isomer	Chemical formula	M_1^a	M_2	$ M_1 - M_2 $
R-123	CHCl_2CF_3	57,0	71,9	14,9
R-123a	CHClFCClF_2	73,4	55,5	17,9
R-123b	$\text{CHF}_2\text{CCl}_2\text{F}$	89,9	39,0	50,9

^a M_i is the sum of the atomic mass of halogens and hydrogens attached to carbon atom i . (C1 is assigned to the rightmost carbon).

A.2 Propane series isomers

[Table A.2](#) illustrates the designation of isomers for the propane series with nine isomers of dichloropentafluoropropane.

Table A.2 — Propane series isomers

Isomer	Chemical Formula	C2 group ^a	M_1^b	M_3	$ M_1 - M_3 $
R-225aa	$\text{CHF}_2\text{CCl}_2\text{CF}_3$	CCl_2	57,0	39,0	18,0
R-225ba	CHClFCClFCF_3	CClF	57,0	55,5	1,5
R-225bb	$\text{CHF}_2\text{CClFCClF}_2$	CClF	73,4	39,0	34,4
R-225ca	$\text{CHCl}_2\text{CF}_2\text{CF}_3$	CF_2	57,0	71,9	14,9
R-225cb	$\text{CHClFCF}_2\text{CClF}_2$	CF_2	73,4	55,5	17,9
R-225cc	$\text{CHF}_2\text{CF}_2\text{CCl}_2\text{F}$	CF_2	89,9	39,0	50,9
R-225da	$\text{CF}_3\text{CHClCClF}_2$	CHCl	73,4	57,0	16,4
R-225ea	$\text{CClF}_2\text{CHFCClF}_2$	CHF	73,4	73,4	0,0
R-225eb	$\text{CF}_3\text{CHFCCl}_2\text{F}$	CHF	89,9	57,0	32,9

^a C2 is the central (second) carbon atom.

^b M_i is the sum of the atomic mass of halogens and hydrogens attached to carbon atom i . (C1 is assigned to the rightmost carbon).

A.3 Propene series isomers

[Table A.3](#) illustrates the designation of isomers of the propene series with seven isomers of tetrafluoro-1-propene.

Table A.3 — Propene series isomers

Isomer	Chemical formula	Stereoisomer
R-1234yc	$\text{CH}_2\text{F}-\text{CF}=\text{CF}_2$	
R-1234zc	$\text{CHF}_2-\text{CH}=\text{CF}_2$	
R-1234ye(E)	$\text{CHF}_2-\text{CF}=\text{CHF}$	Entgegen
R-1234ye(Z)	$\text{CHF}_2-\text{CF}=\text{CHF}$	Zusammen
R-1234ze(E)	$\text{CF}_3-\text{CH}=\text{CHF}$	Entgegen
R-1234ze(Z)	$\text{CF}_3-\text{CH}=\text{CHF}$	Zusammen
R-1234yf	$\text{CF}_3-\text{CF}=\text{CH}_2$	

A.4 Examples of stereoisomers

The configuration of atoms around the double bond is specified by using “E” or “Z” organic nomenclature rules. The letters “E” or “Z” are appended at the end of the refrigerant number to show the precedence of the atoms or groups, which are attached to the carbon atoms at either end of the double bond; see [Figure A.1](#) and [Figure A.2](#). “E” (Entgegen) is similar to trans, where priority atoms or groups are across the double bond from each other. “Z” (Zusammen) is similar to cis, signifying that priority atoms or groups are on the same side of a double bond. Priority order of atoms connected to either of the unsaturated carbons is determined by standard CIP (Cahn-Ingold-Prelog) rules of organic nomenclature. In essence, attached atoms of higher atomic number have higher priority. Hence, in order of priority, $\text{I} > \text{Br} > \text{Cl} > \text{F} > \text{O} > \text{C} > \text{H}$. In case of a priority tie, the next attached atoms or substituents on the next attached carbon atom are considered, until a priority is determined. In the case of refrigerants, it is better to use atomic mass rather than atomic numbers of the atoms. This is because the sum of the atomic numbers of substituents on CHF_2 and CH_2Cl are the same, while the summed atomic masses do differentiate.



Figure A.1 — 1(E)-1,2,3,3-tetrafluoroprop-1-ene, or HFO-1234ye(E)

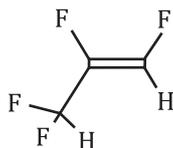


Figure A.2 — 1(Z)-1,2,3,3-tetrafluoroprop-1-ene, or HFO-1234ye(Z)

Annex B (normative)

Details of testing for flammability and fractionation analysis

B.1 Flammability testing

B.1.1 General

Flammability tests shall be conducted in accordance with ASTM E681. Assuming testing a material with a large quenching distance which can be difficult to ignite, the test vessel size shall be a nominal 12 l spherical glass flask as shown in Figure B-1 of ANSI/ASHRAE Standard 34. If testing a material that is not difficult to ignite, refer to the ASTM standard for test vessel description. The ignition source shall be a spark from a transformer secondary rated at 15 kV and 30 mA alternating current (a.c.) as described in ASTM E681, with a 0,4 s spark duration. The electrodes shall be 1 mm, L-shaped tungsten wire electrodes spaced 6,4 mm apart, which extend out of the plane of the electrode holder. The ignition source shall be placed at a height 1/3 from the bottom of the vessel as compared to the diameter of the test vessel. The air used for the tests shall contain $(21,0 \pm 0,1) \% \text{O}_2$. The absolute humidity of the air used for the tests shall be $(0,008 8 \pm 0,000 5)$ g of water vapour per gram of dry air (which equates to 50 % relative humidity at 23,0 °C and 101,3 kPa). The subtended arc shown in Figure B.1 of ANSI/ASHRAE Standard 34 represents the 90° fan for determining LFL and ETFL. A stirrer shall be installed in the flask to ensure mixing of vapours prior to ignition. If flame propagation is observed while the spark is still active (i.e. the spark is overdriving the test vessel), then the test shall be repeated using a spark duration of less than 0,4 s but at least 0,2 s.

Starting concentration of refrigerant for LFL tests shall be less than half of stoichiometric concentration for combustion. Increments of concentration shall be approximately 10 % relatively such as 2 %, 2,2 % and 2,4 %. If the test results in flame propagation, then subsequent testing concentrations shall be at the midpoint of the propagation and no-propagation tests. The tests shall be continued until the concentration step becomes less than 0,1 % absolute or less than 5 % in relative concentration (such as 10 % and 10,5 %) whichever is the greater. If the flame propagation is not reproducible or the extent of flame propagation is not clear, then the results of two out of three tests which agree, either burning or no burning, are considered the results for that concentration. LFL shall be determined to be the midpoint of propagation and no-propagation tests.

If no flame propagation is apparent, testing shall be done until at least three consecutive concentration increments had been made beyond the stoichiometric concentration and beyond the point that combustion around the spark has diminished.

The stoichiometry calculation of a refrigerant blend for combustion tests shall be conducted on the most conservative assumption. The starting point of the LFL test shall be based on stoichiometry of full reaction including combustion of non-flammable components. End point shall be based on a calculation assuming that non-flammable components do not react but are present as diluents.

NOTE Non-flammable components of a blend decompose due to combustion heat of a flammable component in many cases.

WARNING — Flammability test procedures specified in this document are modified procedures of an ASTM test which uses a glass flask as a test vessel. Extreme caution must be employed by test facilities to safeguard against personal injury and equipment damage. Vessels can explode during test. Combustion of refrigerants can produce highly toxic or corrosive products. Testing facilities should consult safety precautions cited in Section 8 of ASTM E681 and run the tests in accordance with relevant regulations.

B.1.2 Test conditions

- a) For single compound refrigerants, flammability tests shall be conducted at 60 °C and ambient pressure between 97,3 kPa and 104,0 kPa.
- b) For refrigerant blends, a fractionation analysis for flammability is not required if the components of the blend are all in one safety group; the blend shall be assigned the same safety group. For refrigerant blends where the components of the blend are not the same safety group, flammability tests shall be conducted on the WCF and WCFF at 60,0 °C and ambient pressure between 97,3 kPa and 104,0 kPa. The WCFF shall be determined by the method specified in [Clause B.2](#). When application of the composition tolerances to the nominal formulation produces several possible worst-case formulations, the applicant shall conduct flammability testing on all possible worst-case formulations or provide sufficient justification for eliminating one or more of the possible worst-case formulations.
- c) For those refrigerants which show flame propagation in accordance with step a) or b), flammability testing shall also be conducted at 23,0 °C and ambient pressure between 97,3 kPa and 104,0 kPa to determine the LFL. For refrigerant blends, these tests shall be conducted on the WCF and the WCFF.

B.1.3 LFL of flammable component(s) is known

When the LFL of the flammable component(s) is known, testing for the refrigerant LFL shall begin at 1 %, by volume, lower than the lowest component LFL. When the component LFL is not known, testing shall begin at 1 % refrigerant by volume. If the test of the initial concentration results in flame propagation, then subsequent testing concentrations shall be reduced in 1 % volume increments until the refrigerant LFL is determined.

B.1.4 Gas chromatography

The mass fraction formulation of the tested blend shall be verified through gas chromatography to a tolerance of $\pm 0,5$ % mass fraction or one fourth of the composition tolerance range, whichever is smaller.

B.1.5 Sample introduction into the test apparatus

Samples shall be introduced into the flammability test apparatus in the vapour phase in accordance with ASTM E681. Liquid samples of the refrigerant or blend composition to be tested shall be expanded into a suitable evacuated container such that only vapour under pressure is present. The vapours shall then be introduced into the flammability test apparatus. Air shall then be added to the test apparatus. Measurement of the refrigerant-to-air concentration shall be by partial pressures. The refrigerant and air shall be mixed in the chamber for at least 5 min. A single activation of the ignition source shall occur within 60 s to 90 s of stirrer deactivation.

B.1.6 Flame propagation

If flame propagation is observed while the spark is still active (i.e. the spark is overdriving the test vessel), then the test shall be repeated using a spark duration of less than 0,4 s but at least 0,2 s.

B.1.7 Flammability test recording

All flammability tests shall be recorded using a video recorder. A playback device capable of freeze frame and single frame advance shall be available during testing. A copy of the video recordings in a digital format such as DVD or MPEG shall be submitted.

B.1.8 Criterion for determining flame propagation

A refrigerant/air concentration shall be considered flammable for flammability classification under this document only if a flame propagation occurs in at least two of three flammability tests on that refrigerant/air concentration. A flame propagation is any combustion that, having moved upward and outward from the point of ignition to the walls of the flask, is continuous along an arc that is greater than that subtended by an angle equal to 90°, as measured from the point of ignition to the walls of the flask.

B.1.9 Flammability test data required

Applications shall include test results for a) to h) listed below. Test conditions shall be controlled to accuracies cited in a) to h) below. Applications shall include tabulated flammability test data for each refrigerant or refrigerant blend composition tested. These data shall include, but are not limited to the following:

- a) Refrigerant or blend composition tested: $\pm 0,1$ % mass fraction
- b) Flammability test temperature: ± 3 K
- c) Fractionation or leak test temperature: $\pm 0,1$ K
- d) Test pressure: 97,3 kPa to 104,0 kPa
- e) Humidity: $\pm 0,000 5$ g of water vapour per gram of dry air
- f) Refrigerant/air concentration: $\pm 0,2$ % volume fractionation
- g) Spark duration: $\pm 0,05$ s
- h) Flame propagation angle measured from the point of ignition to the walls of the flask: $\pm 0,087$ rad [$\pm 5,0^\circ$ (degrees)].

B.2 Fractionation analysis

B.2.1 Reporting results of a fractionation analysis

The applicant shall report results of a fractionation analysis conducted to determine vapour and liquid phase compositions of refrigerant blends under conditions of leakage (see [B.2.4](#)). The analysis shall be validated through experimentation. An analytical model may be used to identify the WCFF. If a model is used, then the applicant shall identify the model used and shall submit sufficient experimental data which validate the model for the refrigerant being evaluated at the conditions which predict the WCFF.

B.2.2 WCF as a starting point

All fractionation analyses shall use the WCF as a starting point. When application of the composition tolerances to the nominal formulation produces several possible worst-case formulations, the applicant shall determine the WCFF for each WCF and provide sufficient justification for eliminating one or more of the possible worst-case formulations.

B.2.3 Gas chromatography

The mass fraction formulation of the tested blend shall be verified through gas chromatography to a tolerance of $\pm 0,5$ % mass fraction or one fourth of the composition tolerance, whichever is smaller.

B.2.4 Leakage testing

B.2.4.1 General

Refrigerant blends containing a flammable component(s) shall be evaluated to determine their worst-case fractionated formulation(s) during storage/shipping or use. Experimental tests or analytical modelling shall be conducted to simulate leaks from:

- a) a container under storage/shipping conditions, and
- b) a container representing air conditioning and refrigeration equipment during normal operation, standby and shipping conditions. The container used for these tests, shall be rated to handle the vapour pressure of the formulation at the highest temperature encountered.

B.2.4.2 Leaks under storage/shipping conditions

To simulate leaks under storage/shipping conditions, the container shall be filled at ambient temperature with the WCF to 90 % of the mass which would result in 100 % liquid fill at 60,0 °C, and then shall be vapour leaked, at a rate that maintains the temperature of the liquid constant within 0,5 K and prevents any liquid from escaping. Tests shall be conducted at the following temperatures.

- a) 60,0 °C;
- b) -40,0 °C or the bubble point at atmospheric pressure plus 10,0 K, whichever is warmer. Tests shall be conducted at the bubble point plus 10,0 K if the bubble point is > -50,0 °C;
- c) the temperature that results in the WCFF between a) and b) if the WCFF does not exist at either a) or b). If no temperature between a) and b) results in the worst-case fractionated formulation (WCFF), then the fractionation test shall be conducted at 23,0 °C. The applicant shall justify and document the determination of the temperature at which the worst-case fractionated formulation occurs.

In the fractionation experiment, the composition of the head space gas and remaining liquid shall be determined by chemical analysis. Analyses shall be made initially after 2 % of the total charge has leaked, next at 10 % loss of the initial mass, then at 10 % mass intervals of the initial mass until atmospheric pressure is reached in the cylinder or no liquid remains. If liquid remains after 90 % of the initial mass is lost and atmospheric pressure has not been reached then a final analysis of head space gas and remaining liquid shall be done at 95 % mass loss.

B.2.4.3 Leaks from equipment

To simulate leaks from equipment, the container shall be filled with the WCF at ambient temperature to 15 % of the mass which would result in 100 % liquid at 60,0 °C and then shall be vapour leaked at the following temperatures:

- a) 60,0 °C.
- b) -40,0 °C or the bubble point at atmospheric pressure plus 10,0 K, whichever is warmer. Tests shall be conducted at the bubble point plus 10,0 K if the bubble point is > -50,0 °C.
- c) the temperature that results in the WCFF between a) and b) if the WCFF does not exist at either a) or b). If no temperature between a) and b) results in the worst-case fractionated formulation (WCFF), then the fractionation test shall be conducted at 23,0 °C. The applicant shall justify and document what constitutes the temperature at which the worst-case fractionated formulation occurs.

In the fractionation experiment, the composition of the head space gas and remaining liquid shall be determined by chemical analysis. Analyses shall be made initially after 2 % of the total charge has leaked, next at 10 % loss of the initial mass, then at 10 % mass intervals of the initial mass until atmospheric pressure is reached in the cylinder or no liquid remains. If liquid remains after 90 % of the initial mass is lost and atmospheric pressure has not been reached then the next and last analysis of head space gas and remaining liquid shall be done at 95 % mass loss.

B.2.5 Fractionation analysis data required

The applicant shall submit for each fractionation scenario:

- a) fractionation or leak test temperature ($\pm 0,10$ K);
- b) tabulated liquid and vapour compositions at each leaked increment ($\pm 0,1$ % mass fraction);
- c) for modelled analysis, model accuracy at conditions which predict the worst-case fractionation formulation (WCFF).

The applicant shall also provide a description of test apparatus and procedures used. If the applicant uses a computer or mathematical model for determining the WCFF, the applicant shall identify the model used and submit supporting data verifying the accuracy of the model against experimental measurements at conditions which predict the WCFF.

Annex C
(normative)

Refrigerant classifications and properties

Refrigerants are assigned the classifications indicated in Tables C.1, C.2, and C.3, available at <https://standards.iso.org/iso/817/ma/en>

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