BS ISO 817:2014

BSI Standards Publication

Refrigerants — Designation and safety classification

National foreword

This British Standard is the UK implementation of ISO 817:2014.

The UK participation in its preparation was entrusted to Technical Committee RHE/18, Refrigeration safety.

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

Published by BSI Standards Limited 2014

ISBN 978 0 580 71018 6
ICS 71.100.45

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2014.

Amendments/corrigenda issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 817

Third edition
2014-05-15

Refrigerants — Designation and safety classification

Fluides frigorigènes — Désignation et classification de sécurité

Reference number
ISO 817:2014(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

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. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

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 WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 8, *Refrigerants and refrigeration lubricants*.

This third edition cancels and replaces the second edition (ISO 817:2005), which has been technically revised.

Introduction

This third edition has been technically revised by the addition of new refrigerant designations and a safety classification system based on toxicity and flammability data.

The safety classifications in this International Standard do not consider decomposition products or by-products of combustion. Product and system safety standards (e.g. ISO 5149, IEC 60335-2-24, IEC 60335-2-34, IEC 60335-2-40 and IEC 60335-2-89) address the prevention of ignition of refrigerant based on the characteristics provided in this International Standard.

Refrigerants — Designation and safety classification

1 Scope

This International Standard 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 and the refrigerant concentration limits are included based on data made available.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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.

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 concentration determined in accordance with the established systems and intended to reduce the risks of acute toxicity hazards to humans in the event of a refrigerant release

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

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 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 LC_{50} test

3.1.5
azeotrope
blend composed of two or more refrigerants whose equilibrium vapour and liquid phase compositions are the same at a specific pressure, but may be different at other conditions

3.1.6
blend
mixture composed of two or more refrigerants

3.1.7
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 with air giving the maximum velocity

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

3.1.8
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

3.1.9
chronic toxicity
adverse health effect(s) from long-term repeated exposures

3.1.10
combustion
exothermal reaction between an oxidant component (combustive) and a reducer (combustible fuel)

3.1.11
compound
substance composed of two or more atoms chemically bonded in definite proportions

3.1.12
critical point
point with conditions above which distinct liquid and gas phases do not exist

3.1.13
cyclic compound
organic compound whose structure is characterized by a closed ring of atoms

3.1.14
effective concentration 50 %
EC_{50}
concentration of a refrigerant, 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.

3.1.15
elevated temperature flame limit
ETFL
minimum concentration by volumic ratio (volume per cent) of the refrigerant, which is capable of propagating a flame 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.

3.1.16
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)/$(\text{combustible fraction})_{\mathrm{st}}$.

Note 2 to entry: It is used in the determination of burning velocity.

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

3.1.17
flame
collection of gases of a rapid combustion, generally visible due to the emission of light

3.1.18
flame propagation
combustion, causing a continuous flame 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.1.7. Flame propagation as applied in the test method for determining burning velocity is described in Annex C.

3.1.19
flammable
property of a mixture in which a flame is capable of self-propagating for a certain distance

3.1.20
fractionation
change in composition of a blend by preferential evaporation of the more volatile component(s) or condensation of the less volatile component(s)

3.1.21
heat of combustion
HOC
heat evolved from a specified 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 International Standard is expressed as a positive value for exothermic reactions in energy per unit mass (kJ/kg).

3.1.22
isomers
two or more compounds having the same chemical composition with differing molecular configurations

3.1.23
lethal concentration 50 %
LC_{50}
concentration that is lethal to 50 % of the test animals

3.1.24
lower flammability limit
LFL
minimum concentration of the refrigerant that is capable of propagating a flame 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.

3.1.25
lowest observed adverse effect level
LOAEL
lowest concentration of a refrigerant that causes any observed adverse effect in one or more test animals

3.1.26
no observed adverse effect level
NOAEL
highest concentration of a refrigerant at which no adverse effect is observed in any of the exposed animal population

3.1.27
nominal composition
nominal formulation
design composition as stated in the refrigerant blend application, excluding any tolerances

Note 1 to entry: Composition of the refrigerant blends shall be as listed in Tables 6 and 7, column 2.

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

3.1.28
occupational exposure limit
time-weighted average concentration for a normal eight-hour work day and a 40-hour work week to which nearly all workers can be repeatedly exposed without adverse effect

Note 1 to entry: It is based on national regulations, such as OSHA PEL, ACGIH TLV-TWA, TERA WEEL, or MAK.

3.1.29
olefin
unsaturated chemical compound containing at least one carbon-to-carbon double bond

3.1.30
organic compound, saturated
carbon-containing compound that has only single bonds between carbon atoms

3.1.31
organic compound, unsaturated
carbon-containing compound containing at least one double or triple bond between carbon atoms

3.1.32
oxygen deprivation limit
ODL
concentration of a refrigerant or other gas that can result in insufficient oxygen for normal breathing

3.1.33
propagation velocity of flame
velocity at which a flame propagates in a space

3.1.34
quenching
effect of extinction of a flame as it approaches a surface due to heat conduction losses, absorption of active chemical species and viscous effects on the surface

3.1.35
refrigerant
fluid used for heat transfer in a refrigerating system, which 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

3.1.36
refrigerant concentration limit
RCL
maximum refrigerant concentration, in air, determined and established to reduce the risks of acute toxicity, asphyxiation and flammability hazards

Note 1 to entry: It is determined in accordance with this International Standard.

3.1.37
relative molar mass
mass numerically equal to the molecular mass expressed in grams per mole, except that it is dimensionless

3.1.38
stoichiometric concentration for combustion
C_{st}
concentration of a fuel in a fuel–air mixture that contains exactly the necessary quantity of air (21 % O_2/79 % N_2 by volume) needed for the complete oxidation of all the compounds present

3.1.39
threshold limit value-time weighted average
TLV-TWA
time weighted average concentration for a normal eight-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect

3.1.40
workplace environmental exposure limit
WEEL
occupational exposure limit set by the Toxicology Excellence for Risk Assessment (TERA)

3.1.41
worst-case formulation
WCF
composition that results from application of the tolerances to the nominal composition resulting in the most toxic or the most flammable formulation

3.1.42
worst-case fractionated formulation
WCFF
composition produced during fractionation of the worst-case formulation that results in the most toxic or most flammable formulation

3.1.43
zeotrope
blend composed of two or more refrigerants whose equilibrium vapour and liquid phase compositions are not the same at any pressure below the critical pressure

3.2 Abbreviated terms

ALC	approximate lethal concentration
ATEL	acute-toxicity exposure limit
CNS	central nervous system effect
EC_{50}	effective concentration 50 %
ETFL	elevated temperature flame limit
HOC	heat of combustion
LC_{50}	lethal concentration 50 %
LFL	lower flammability limit
LOAEL	lowest observed adverse effect level
MAK	Maximale Arbeitsplatz-Konzentration (Maximum workplace concentration) as set by Deutsche Forschungsgemeinschaft (German Research Foundation)
NOAEL	no observed adverse effect level
ODL	oxygen deprivation limit
PEL	permissible exposure limit
RCL	refrigerant concentration limit
RCL_M	RCL expressed as grams per cubic metre
RCL_{ppm}	RCL expressed as parts per million by volume
TCF	toxic concentration factor
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}	cardiac sensitization indicator of 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 centimetres per second
S_{u}	burning velocity, expressed in centimetres per second
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 An identifying number shall be assigned to each refrigerant. Assigned numbers and safety classifications are shown in Tables 5, 6 and 7. Tables E.4, E.5 and E.6 provide designations for refrigerants for which insufficient data are available for safety classification or determination of an ATEL or RCL value.

4.2 The identifying numbers assigned to the hydrocarbons, halocarbons and ethers of the methane, ethane, ethene, propane, propene 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.

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

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

4.2.3 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.

4.2.4 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.

4.2.5 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 4.2.1 to 4.2.4 shows the presence of bromine or iodine. The number following the letter B or I shows the number of bromine or iodine atoms present.

4.2.6 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.

4.2.7 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, 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.

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

4.2.9 In the case of isomers in the ethane 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 (i.e. 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.

4.2.10 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, $CF_3CF_2CF_3$ is designated R-218, not R218ca. An example of this system is given in Annex A. Propane series isomers containing bromine are not covered by the appended letters given in 4.2.11 and Table 2.

4.2.11 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

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).

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

4.3.1 Two-carbon, dimethyl ethers (e.g. R-E125, CHF_2-O-CF_3) require no suffixes other than those specified in 4.2.9, as the presence of the “E” prefix provides an unambiguous description.

4.3.2 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.

4.3.2.1 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, CHF_2-O-CHF-CF_3).

4.3.2.2 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.

4.3.2.3 In those cases where only a single isomer exists for the hydrocarbon portion of the ether structure, such as CF_3-O-CF_2-CF_3, the suffix letters described in 4.2.9, 4.2.10 and 4.2.11 shall be omitted. In this cited example, the correct designation shall be R-E218.

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

4.3.3 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 3.2.

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

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

4.4.2 Azeotropes shall be serially 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, ...) is added after the number.

4.4.3 Blends shall have tolerances specified for individual components. Those tolerances shall be specified to the nearest 0,1 % mass fraction. The maximum tolerance above or below the nominal shall not exceed 2,0 % mass fraction. The tolerance above or below the nominal shall not be less than 0,1 % mass fraction. The difference between the highest and the lowest tolerances shall not exceed one-half of the nominal component composition.

4.5 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. For example, 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 3. For example, 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 or 500 series.

Table 3 — 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 shall be assigned identifying numbers in the 700 series and 7000 series.

4.6.1 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.

4.6.2 For compounds with 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.

4.6.3 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, or HFC to refer to chlorofluorocarbon, hydrochlorofluorocarbon, or hydrofluorocarbon, respectively, or with substitution of an O for the carbon C as CFO, HCFO, or HFO to refer to chlorofluoro-olefin, hydrochlorofluoro-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 4.

Table 4 — 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	$CF3CF_3$	PFC-116
Hydrocarbon 600a	$(CH_3)_2CH\ CH_3$	HC-600a
Perfluorocarbon C318	$-(CF_2)_4-$	PFC-C318
Hydrofluoroether E125	CHF_2OCF_3	HFE-125
Hydrofluoro-olefin 1234yf	$CF_3CF=CH_2$	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 dual safety group classification, with the two classifications separated by a slash (/). The first classification listed shall be the classification of the worst-case formulation (WCF) of the blend. The second classification listed shall be the classification of the worst-case fractionated formulation (WCFF).

6.1.2 Toxicity classification

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

— class A (lower chronic toxicity) signifies refrigerants that have an occupational exposure limit of 400 ppm[1] or greater;

— class B (higher chronic toxicity) signifies refrigerants that have an occupational exposure limit of less than 400 ppm.

NOTE The occupational exposure limit is based on the OSHA PEL, ACGIH TLV-TWA, TERA WEEL, or the MAK.

6.1.3 Flammability classification — General

6.1.3.1 Flammability classification

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 specified below.

Burning velocity measurements shall be conducted according to Annex C or other credible method. The selected method shall be in agreement with established methods of determining burning velocity by demonstrating to the ISO 817 Maintenance Agency (MA) measurement results of 6,7 ± 0,7 cm/s burning velocity for R-32 and 23,0 ± 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 2 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 ±0,1 % in the test chamber. Dry reconstituted air (less than 0,000 15 g of water vapour per gram of dry air) containing 21,0 ± 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.[14]

---

1) 0,01 vol % (per cent volume fraction) is the equivalent of 100 ppm; ppm is a deprecated unit at ISO.

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 WCF and 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 (WCF and WCFF) that meet all of the following conditions:

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

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.),

c) have a heat of combustion < 19 000 kJ/kg (see 6.1.3.7), and.

d) 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 (WCF and WCFF) that meet all of the following conditions:

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

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.), 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 WCF and 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

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

6.1.3.7.1 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, CO_2 (N_2, SO_2 if nitrogen or sulfur 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 H_2O. 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 COF_2 in preference to the formation of CO_2. The remaining Cl produces Cl_2.

6.1.3.7.2 For refrigerant blends, the heat of combustion of the nominal composition shall be calculated from a balanced stoichiometric equation 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 6.1.3.7.1. 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 Figure 1.

	Safety group	
Higher Flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

Figure 1 — Safety groups as determined by flammability and toxicity

7 Refrigerant classifications

Refrigerants are assigned the classifications indicated in Tables 5, 6 and 7.

8 Refrigerant concentration limit (RCL)

8.1 General

Determination of the RCL 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.

The RCL for each refrigerant shall be the lowest of the quantities calculated in accordance with 8.1.1.1, 8.1.2 and 8.1.3, using data as indicated in 8.2, and adjusted in accordance with 8.4 unless there is a valid scientific argument to support an alternative value.

8.1.1 General

8.1.1.1 Acute-toxicity exposure limit (ATEL)

The ATEL shall be the lowest of the toxic concentration factors (TCF) 8.1.1.2, 8.1.1.3, 8.1.1.4 and 8.1.1.5. For blends, the individual parameter values in 8.1.1.1 to 8.1.1.5 shall be calculated according to the following formula:

$$\frac{1}{C_{\text{blend}}} = \frac{x_1}{C_1} + \frac{x_2}{C_2} + \ldots + \frac{x_n}{C_n}$$

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.

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

8.1.1.2 Mortality

Value shall be chosen according to the following priority.

First priority: 28,3 % of the 4-h LC_{50} 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 LC_{50} 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[1].

Formulae (1) and (2) shall be used to adjust LC_{50} or ALC values that were determined with 15-min to 8-h tests, for refrigerants for which 4-h data are not available:

$$LC_{50(t1)} = LC_{50(t2)} \times (t_2/t_1)^{1/2} \tag{1}$$

and

$$ALC_{t1} = ALC_{t2} \times (t_2/t_1)^{1/2} \tag{2}$$

where

t_1 is 4 h;

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

8.1.1.3 Cardiac sensitization

The cardiac sensitization study is not required in the ATEL determination if the 4-h LC_{50} or 4-h ALC in 8.1.1.3 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. None of the hydrocarbons or hydrohalocarbons that have low LC_{50} have ever been shown to cause cardiac arrhythmias.[13]

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 emergence of other effects (e.g. tremors or anaesthesia) precludes the ability to determine a cardiac sensitization value.

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

Third priority: if no value can be determined, consideration may be given to cardiac sensitization data derived from other similar compounds provided there is a good scientific justification. If cardiac sensitization data are not determined, the NOAEL is assigned a value of 1 000 ppm.

8.1.1.4 Anaesthetic or central nervous system (CNS) effects

Value shall be chosen according to the following priority.

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

Second priority: 100 % 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.

8.1.1.5 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.

8.1.2 Oxygen deprivation limit (ODL)

The ODL shall be 140 000 ppm by volume of refrigerant in air (18 % O_2) 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 % O_2).

8.1.3 Flammable concentration limit (FCL)

The FCL shall be expressed in parts per million[1)] and calculated as 20 % of the LFL, expressed in ppm, and determined in accordance with Annex B.

8.2 Data for calculations

8.2.1 Data sources

8.2.1.1 Data for calculations: the data used to calculate the RCL 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 under Annex F, for toxicity data shall indicate the extent of compliance with good laboratory practices (GLP) in effect when the studies were performed, for example Reference [6]. 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. 8.1.1.1, 8.1.1.2, 8.1.1.3, and 8.1.1.4, or involving chemical analogues, may be submitted to the ISO 817 Maintenance Agency (see Annex F) 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 8.1.1.3 and 8.1.1.4, 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 8.1.1.2, 8.1.1.3, 8.1.1.4 and 8.1.1.5 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 RCL. Also identify limits for those impurities. See AHRI Standard 700.

8.4 Conversion of units — Volumic mass and altitude adjustment

Formula (3) shall be used to convert the RCL from a volumetric ratio (ppm by volume) to volumic mass (g/m^3):

$$\mathrm{RCL_M} = \mathrm{RCL_{ppm}} \times a \times \mathrm{M} \times 10^{-6} \tag{3}$$

where

$\mathrm{RCL_M}$ is the RCL (g/m^3);

$\mathrm{RCL_{ppm}}$ is the RCL (ppm by volume);

M is the relative molar mass of the refrigerant (g/mol).

$a = P/RT$

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.

Table 5 — Refrigerant designations

Refrigerant number	Composition designating prefix	Chemical name[b]	Chemical formula	Relative molar mass[a] g/mol	Normal boiling point[a] °C	Safety group[d]	LFL (ppm by volume)	ATEL (ppm by volume)	RCL (ppm by volume)
		Methane series							
R-11	CFC	trichlorofluoromethane	CCl_3F	137,4	24	A1		1 100	1 100
R-12	CFC	dichlorodifluoromethane	CCl_2F_2	120,9	-30	A1		18 000	18 000
R-14	PFC	tetrafluoromethane (carbon tetrafluoride)	CF_4	88,0	-128	A1		110 000	110 000
R-22	HCFC	chlorodifluoromethane	$CHClF_2$	86,5	-41	A1		59 000	59 000
R-23	HFC	trifluoromethane	CHF_3	70,0	-82	A1		51 000	51 000
R-32	HFC	difluoromethane (methylene fluoride)	CH_2F_2	52,0	-52	A2L	144 000	220 000	29 000
		Ethane series							
R-113	CFC	1,1,2-trichloro-1,2,2-trifluoroethane	CCl_2FCClF_2	187,4	48	A1		2 600	2 600
R-114	CFC	1,2-dichloro-1,1,2,2-tetrafluoroethane	$CClF_2CClF_2$	170,9	4	A1		20 000	20 000
R-115	CFC	chloropentafluoroethane	$CClF_2CF_3$	154,5	-39	A1		120 000	120 000
R-116	PFC	hexafluoroethane	CF_3CF_3	138,0	-78	A1		120 000	120 000
R-123	HCFC	2,2-dichloro-1,1,1-trifluoroethane	$CHCl_2CF_3$	153,0	27	B1		9 100	9 100
R-124	HCFC	2-chloro-1,1,1,2-tetrafluoroethane	$CHClFCF_3$	136,5	-12	A1		10 000	10 000
R-125	HFC	pentafluoroethane	CHF_2CF_3	120,0	-49	A1		75 000	75 000
R-134a	HFC	1,1,1,2-tetrafluoroethane	CH_2FCF_3	102,0	-26	A1		50 000	50 000
R-142b	HCFC	1-chloro-1,1-difluoroethane	CH_3CClF_2	100,5	-10	A2	80 000	25 000	16 000
R-143a	HFC	1,1,1-trifluoroethane	CH_3CF_3	84,0	-47	A2L	82 000	170 000	16 000
R-152a	HFC	1,1-difluoroethane	CH_3CHF_2	66,0	-25	A2	48 000	50 000	9 600
R-170	HC	ethane	CH_3CH_3	30,0	-89	A3	31 000	7 000	6 200
R-E170		methoxymethane (dimethyl ether)	CH_3OCH_3	46,1	-25	A3	34 000	42 000	6 800
		Propane series							
R-218	PFC	octafluoropropane	$CF_3CF_2CF_3$	188,0	-37	A1		110 000	110 000
R-227ea	HFC	1,1,1,2,3,3,3-heptafluoropropane	CF_3CHFCF_3	170,0	-16	A1		90 000	90 000
R-236fa	HFC	1,1,1,3,3,3-hexafluroropropane	$CF_3CH_2CF_3$	152,0	-1	A1		55 000	55 000
R-245fa	HFC	1,1,1,3,3-pentafluoropropane	$CHF_2CH_2CF_3$	134,0	15	B1		34 000	34 000
R-290	HC	propane	$CH_3CH_2CH_3$	44,0	-42	A3	21 000	50 000	4 200

Table 5 *(continued)*

Refrigerant number	Composition designating prefix	Chemical name[b]	Chemical formula	Relative molar mass[a] g/mol	Normal boiling point[a] °C	Safety group[d]	LFL (ppm by volume)	ATEL (ppm by volume)	RCL (ppm by volume)
		Cyclic organic compound							
R-C318	PFC	octafluorocyclobutane	$\underbracket{CF_2CF_2CF_2CF_2}$	200,0	-6	A1		80 000	80 000
		Misc. organic compounds **Hydrocarbons**							
R-600	HC	butane	$CH_3CH_2CH_2CH_3$	58,1	0	A3	16 000	1 000	1 000
R-600a	HC	2-methylpropane (isobutane)	$(CH_3)_2CHCH_3$	58,1	-12	A3	18 000	25 000	3 600
R-601	HC	pentane	$CH_3CH_2CH_2CH_2CH_3$	72,2	36	A3	12 000	1 000	1 000
R-601a	HC	2-methylbutane (isopentane)	$(CH_3)_2CHCH_2CH_3$	72,2	27	A3	10 000	1 000	1 000
		Inorganic compounds							
R-702		hydrogen	H_2	2,0	-253	A3	40 000		
R-704		helium	He	4,0	-269	A1			
R-717		ammonia	NH_3	17,0	-33	B2L	167 000	320	320
R-744		carbon dioxide	CO_2	44,0	-78[c]	A1		40 000	40 000
		Propene series							
R-1234yf	HFO	2,3,3,3-tetrafluoro-1-propene	$CF_3CF{=}CH_2$	114,0	-29,4	A2L	62 000	100 000	12 000
R-1234ze(E)	HFO	trans-1,3,3,3-tetrafluoro-1-propene	$CF_3CH{=}CHF$	114,0	-19,0	A2L	65 000	59 000	13 000
R-1270	HC	propene (propylene)	$CH_3CH{=}CH_2$	42,1	-48	A3	27 000	1 000	1 000

[a] The relative molar mass and normal boiling point are not part of this International Standard. The normal boiling point is the temperature at which a liquid substance boils at standard atmospheric pressure (101,3 kPa).

[b] The preferred chemical name is followed by the popular name in parentheses. The preferred chemical name and formula are in accordance with Reference [3] or Reference [4].

[c] Sublimes.

[d] Table E.4 provides designations for single-compound refrigerants for which insufficient data are available for safety classification or determination of an ATEL or RCL value.

Table 6 — Refrigerant designations of R400 blends

Refrigerant number	**Nominal composition**[c] mass fraction %	**Composition tolerance** %	**Bubble point/ dew point at** 101,3 kPa °C[a]	**Safety group**[d]	**LFL** (ppm by volume)	**ATEL** (ppm by volume)	**RCL** (ppm by volume)
R-401A	R-22/152a/124 (53,0/13,0/34,0)	±2,0/+0,5-1,5/±1,0	-34,4/-28,8	A1/A1		27 000	27 000
R-401B	R-22/152a/124 (61,0/11,0/28,0)	±2,0/+0,5-1,5/±1,0	-35,7/-30,8	A1/A1		30 000	30 000
R-401C	R-22/152a/124 (33,0/15,0/52,0)	±2,0/+0,5-1,5/±1,0	-30,5/-23,8	A1/A1		20 000	20 000
R-402A	R-125/290/22 (60,0/2,0/38,0)	±2,0/+0,1-1,0/±2,0	-49,2/-47,0	A1/A1		66 000	66 000
R-402B	R-125/290/22 (38,0/2,0/60,0)	±2,0/+0,1-1,0/±2,0	-47,2/-44,9	A1/A1		63 000	63 000
R-403A	R-290/22/218 (5,0/75,0/20,0)	+0,2-2,0/±2,0/±2,0	-44,0/-42,3	A1/A2	130 000	63 000	26 000
R-403B	R-290/22/218 (5,0/56,0/39,0)	+0,2-2,0/±2,0/±2,0	-43,8/-42,3	A1/A1		68 000	68 000
R-404A	R-125/143a/134a (44,0/52,0/4,0)	±2,0/±1,0/±2,0	-46,6/-45,8	A1/A1		130 000	130 000
R-406A	R-22/600a/142b (55,0/4,0/41,0)	±2,0/±1,0/±1,0	-32,7/-23,5	A2/A2	82 000	37 000	16 000
R-407A	R-32/125/134a (20,0/40,0/40,0)	±2,0/±2,0/±2,0	-45,2/-38,7	A1/A1		83 000	83 000
R-407B	R-32/125/134a (10,0/70,0/20,0)	±2,0/±2,0/±2,0	-46,8/-42,4	A1/A1		79 000	79 000
R-407C	R-32/125/134a (23,0/25,0/52,0)	±2,0/±2,0/±2,0	-43,8/-36,7	A1/A1		81 000	81 000
R-407D	R-32/125/134a (15,0/15,0/70,0)	±2,0/±2,0/±2,0	-39,4/-32,7	A1/A1		68 000	68 000
R-407E	R-32/125/134a (25,0/15,0/60,0)	±2,0/±2,0/±2,0	-42,8/-35,6	A1/A1		80 000	80 000
R-407F	R-32/125/134a (30,0/30,0/40,0)	±2,0/±2,0/±2,0	-46,1/-39,7	A1/A1		95 000	95 000
R-408A	R-125/143a/22 (7,0/46,0/47,0)	±2,0/±1,0/±2,0	-45,5/-45,0	A1/A1		94 000	94 000
R-409A	R-22/124/142b (60,0/25,0/15,0)	±2,0/±2,0/±1,0	-35,4/-27,5	A1/A1		29 000	29 000
R-409B	R-22/124/142b (65,0/25,0/10,0)	±2,0/±2,0/±1,0	-36,5/-29,7	A1/A1		30 000	30 000
R-410A	R-32/125 (50,0/50,0)	+0,5-1,5/+1,5-0,5	-51,6/-51,5	A1/A1		170 000	140 000
R-410B	R-32/125 (45,0/55,0)	±1,0/±1,0	-51,5/-51,4	A1/A1		150 000	140 000
R-411A	R-1270/22/152a (1,5/87,5/11,0)	+0,0-1,0/+2,0-0,0/+0,0-1,0	-39,7/-37,2	A1/A2	55 000	22 000	11 000
R-411B	R-1270/22/152a (3,0/94,0/3,0)	+0,0-1,0/+2,0-0,0/+0,0-1,0	-41,6/-41,3	A1/A2	70 000	13 000	13 000
R-412A	R-22/218/142b (70,0/5,0/25,0)	±2,0/±2,0/±1,0	-36,4/-28,8	A1/A2	87 000	46 000	17 000
R-413A	R-218/134a/600a (9,0/88,0/3,0)	±1,0/±2,0/+0,0-1,0	-29,3/-27,6	A1/A2	88 000	49 000	18 000
R-414A	R-22/124/600a/142b (51,0/28,5/4,0/16,5)	±2,0/±2,0/±0,5/+0,5-1,0	-34,0/-25,8	A1/A1		26 000	26 000
R-414B	R-22/124/600a/142b (50,0/39,0/1,5/9,5)	±2,0/±2,0/±0,5/+0,5-1,0	-34,4/-26,1	A1/A1		23 000	23 000
R-415A	R-22/152a (82,0/18,0)	±1,0/±1,0	-37,5/-34,7	A1/A2	56 000	57 000	11 000

Table 6 *(continued)*

Refrigerant number	Nominal composition[c] mass fraction %	Composition tolerance %	Bubble point/ dew point at 101,3 kPa °C[a]	Safety group[d]	LFL (ppm by volume)	ATEL (ppm by volume)	RCL (ppm by volume)
R-415B	R-22/152a (25,0/75,0)	±1,0/±1,0	-23,4/-21,8	A2/A2	47 000	52 000	9 400
R-416A	R-134a/124/600 (59,0/39,5/1,5)	+0,5-1,0/+1,0-0,5/+0,1-0,2	-23,4/-21,8	A1/A1		14 000	14 000
R-417A	R-125/134a/600 (46,6/50,0/3,4)	±1,1/±1,0/+0,1-0,4	-38,0/-32,9	A1/A1		13 000	13 000
R-417B	R-125/134a/600 (79,0/18,3/2,7)	±1,0/±1,0/+0,1-0,5	-44,9/-41.5	A1/A1		15,000	15,000
R-418A	R-290/22/152a (1,5/96,0/2,5)	±0,5/±1,0/±0,5	-41,2/-40,1	A1/A2	89 000	59 000	18 000
R-419A	R-125/134a/E170 (77,0/19,0/4,0)	±1,0/±1,0/±1,0	-42,6/-36,0	A1/A2	60 000	70 000	12 000
R-420A	R-134a/142b (88,0/12,0)	+1,0 −0,0/+0,0 −1,0	-25,0/-24,2	A1/A1		45 000	45 000
R-421A	R-125/134a (58,0/42,0)	±1,0/±1,0	-40,8/-35,5	A1/A1		61 000	61 000
R-421B	R-125/134a (85,0/15,0)	±1,0/±1,0	-45,7/-42,6	A1/A1		69 000	69 000
R-422A	R-125/134a/600a (85,1/11,5/3,4)	±1,0/±1,0/+0,1 −0,4	-46,5/-44,1	A1/A1		63 000	63 000
R-422B	R-125/134a/600a (55,0/42,0/3,0)	±1,0/±1,0/+0,1 −0,5	-40,5/-35,6	A1/A1		56 000	56 000
R-422C	R-125/134a/600a (82,0/15,0/3,0)	±1,0/±1,0/+0,1 −0,5	-45,3/-42,3	A1/A1		62 000	62 000
R-422D	R-125/134a/600a (65,1/31,5/3,4)	+0,9 −1,1/±1,0/+0,1 −0,4	-43,2/-38,4	A1/A1		58 000	58 000
R-423A	R-134a/227ea (52,5/47,5)	±1,0/±1,0	-24,2/-23,5	A1/A1		59 000	59 000
R-424A	R-125/134a/600a/600/601a (50,5/47,0/0,9/1,0/0,6)	±1,0/±1,0/+0,1 −0,2/+0,1 −0,2/+0,1 −0,2	-39,1/-33,3	A1/A1		23 000	23 000
R-425A	R-32/134a/227ea (18,5/69,5/12,0)	±0,5/±0,5/±0,5	-38,1/-31,3	A1/A1		72 000	72 000
R-426A	R-125/134a/600/601a (5,1/93,0/1,3/0,6)	±1,0/±1,0/+0,1 −0,2/+0,1 −0,2	-28,5/-26,7	A1/A1		20 000	20 000
R-427A	R-32/125/143a/134a (15,0/25,0/10,0/50,0)	±2,0/±2,0/±2,0/±2,0	-43,0/-36,3	A1/A1		79 000	79 000
R-428A	R-125/143a/290/600a (77,5/20,0/0,6/1,9)	±1,0/±1,0/+0,1 −0,2/+0,1 −0,2	-48,3/-47,5	A1/A1		83 000	83 000
R-429A	R-E170/152a/600a (60,0/10,0/30,0)	±1,0/±1,0/±1,0	-26,0/-25.6	A3/A3	25 000	47 000	5 000
R-430A	R-152a/600a (76,0/24,0)	±1,0/±1,0	-27,6/-27,4	A3/A3	32 000	40 000	6 400
R-431A	R-290/152a (71,0/29,0)	±1,0/±1,0	-43,1/-43,1	A3/A3	22 000	50 000	4 400
R-432A	R-1270/E170 (80,0/20,0)	±1,0/±1,0	-46,6/-45,6	A3/A3	22 000	1 200	1 200
R-433A	R-1270/290 (30,0/70,0)	±1,0/±1,0	-44,6/-44,2	A3/A3	20 000	3 100	3 100
R-433B	R-1270/290 (5,0/95,0)	±1,0/±1,0	-42,7/-42,5	A3/A3	18 000	14 000	3 600
R-433C	R-1270/290 (25,0/75,0)	±1,0/±1,0	-44,3/-43,9	A3/A3	18,000	3 600	3 600
R-434A	R-125/143a/134a/600a (63,2/18,0/16,0/2,8)	±1,0/±1,0/±1,0/+0,1 −0,2	-45,0/-42,3	A1/A1		73 000	73 000
R-435A	R-E170/152a (80,0/20,0)	±1,0/±1,0	-26,1/-25,9	A3/A3	34 000	45 000	6 800

Table 6 *(continued)*

Refrigerant number	**Nominal composition**[c] mass fraction %	**Composition tolerance** %	**Bubble point/ dew point at** 101,3 kPa °C[a]	**Safety group**[d]	**LFL** (ppm by volume)	**ATEL** (ppm by volume)	**RCL** (ppm by volume)
R-436A	R-290/600a (56,0/44,0)	±1,0/±1,0	-34,3/-26,2	A3/A3	16 000	36 000	3 200
R-436B	R-290/600a (52,0/48,0)	±1,0/±1,0	-33,4/-25,0	A3/A3	16 000	35 000	3 200
R-437A	R-125/134a/600/601 (19,5/78.5/1,4/0,6)	+0,5 −1,8/+1,5 −0,7/+0,1 −0,2/+0,1 −0,2	-32,9/-29,2	A1/A1		19 000	19 000
R-438A	R-32/125/134a/600/601a (8,5/45,0/44,2/1,7/0,6)	+0,5 −1,5/±1,5/±1,5/+0,1 −0,2/+0,1 −0,2	-43,0/-36,4	A1/A1		19 000	19 000
R-439A	R-32/125/600a (50,0/47,0/3,0)	±1,0/±1,0/±0,5	-52,0/-51,8	A2/A2	104 000	140 000	21 000
R-440A	R-290/134a/152a (0,6/1,6/97,8)	±0,1/±0,6/±0,5	-25,5/-24,3	A2/A2	46 000	50 000	9 200
R-441A	R-170/290/600a/600 (3,1/54,8/6,0/36,1)	±0,3/±2,0/±0,6/±2,0	-41,9/-20,4	A3/A3	16 000	3 200	3 200
R-442A	R-32/125/134a/152a/227ea (31,0/31,0/30,0/3,0/5,0)	±1,0/± 1,0± 1,0/±0,5/±1,0	-46,5/-52,7	A1/A1		100 000	100 000

[a] The “bubble point” and the “dew point” temperatures are not part of this International Standard; they are provided for information only. The “bubble point” is defined as the liquid saturation temperature of a refrigerant; the temperature at which a liquid refrigerant first begins to boil. The “dew point” is defined as the vapour saturation temperature of a refrigerant; the temperature at which the last drop of liquid refrigerant boils. The dew point of a zeotropic refrigerant blend, at constant pressure, is higher than the bubble point.

[b] The composition tolerances for the sum of R152a and R142b are (+0/−2).

[c] Blend components are conventionally listed in order of increasing normal boiling point.

[d] Table E.5 provides designations for R400 refrigerant blends for which insufficient data are available for safety classification or determination of an ATEL or RCL value.

Table 7 — Refrigerant designations of R500 blends

Refrigerant number	**Nominal composition**[e] (mass %)	**Composition tolerance** %	**Azeotropic temperature** °C[d]	**Bubble point/ dew point at** 101,3 kPa °C[a,b]	**Safety group**[f]	**LFL** (ppm by volume)	**ATEL** (ppm by volume)	**RCL** (ppm by volume)
R-500	R-12/152a (73,8/26,2)	+1,0-0,0/+0,0-1,0	0	-33,6/-33,6	A1/A1		30 000	30 000
R-501	R-22/12 (75,0/25,0)[c]		-41	-40,5/-40,3	A1/A1		54 000	54 000
R-502	R-22/115 (48,8/51,2)		19	-45,3/-45,0	A1/A1		73 000	73 000
R-507A	R-125/143a (50,0/50,0)	+1,5-0,5/+0,5-1,5	-40	-47,1/-47,1	A1/A1		130 000	130 000
R-508A	R-23/116 (39,0/61,0)	±2,0/±2,0	-86	-87,4/-87,4	A1/A1		69 000	69 000
R-508B	R-23/116 (46,0/54,0)	±2,0/±2,0	-46	-87,4/-87,0	A1/A1		65 000	65 000
R-509A	R-22/218 (44,0/56,0)	±2,0/±2,0	0	-40,4/-40,4	A1/A1		75 000	75 000
R-510A	R-E170/600a (88,0/12,0)	±0,5/±0,5	-25,2	-25,2/-25,2	A3/A3	29 000	45 000	5 800
R-511A	R-290/E170 (95,0/5,0)	±1,0/± 1,0	–20 to 40	-42,18/-42,1	A3/A3	21 000	51 000	4 200
R-512A	R-134a/152a (5,0/95,0)	±1,0/± 1,0	-20 to 40	-24,0/-24,0	A2/A2	45 000	50 000	9 000

[a] The “bubble point” and the “dew point” temperatures are not part of this International Standard; they are provided for information only. The “bubble point” is defined as the liquid saturation temperature of a refrigerant; the temperature at which a liquid refrigerant first begins to boil. The “dew point” is defined as the vapour saturation temperature of a refrigerant; the temperature at which the last drop of liquid refrigerant boils. The dew point of a zeotropic refrigerant blend, at constant pressure, is higher than the bubble point.

[b] Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they are formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.

[c] The exact composition of this azeotrope is in question, and additional experimental studies are needed.

[d] Under vapour-liquid equilibrium conditions.

[e] Blend components are listed in order of increasing normal boiling point.

[f] Table E.6 provides designations for R500 refrigerant blends for which insufficient data are available for safety classification or determination of an ATEL or RCL value.

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	$\lvert M_1 - M_2 \rvert$
R-123	$CHCl_2CF_3$	57,0	71,9	14,9
R-123a	$CHClFCClF_2$	73,4	55,5	17,9
R-123b	CHF_2CCl_2F	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	$\lvert M_1 - M_3 \rvert$
R-225aa	$CHF_2CCl_2CF_3$	CCl_2	57,0	39,0	18,0
R-225ba	$CHClFCClFCF_3$	CClF	57,0	55,5	1,5
R-225bb	$CHF_2CClFCClF_2$	CClF	73,4	39,0	34,4
R-225ca	$CHCl_2CF_2CF_3$	CF_2	57,0	71,9	14,9
R-225cb	$CHClFCF_2CClF_2$	CF_2	73,4	55,5	17,9
R-225cc	$CHF_2CF_2CCl_2F$	CF_2	89,9	39,0	50,9
R-225da	$CF_3CHClCClF_2$	CHCl	73,4	57,0	16,4
R-225ea	$CClF_2CHFCClF_2$	CHF	73,4	73,4	0,0
R-225eb	$CF3CHFCCl_2F$	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	CH_2F-CF=CF_2	
R-1234zc	CHF_2-CH=CF_2	
R-1234ye(E)	CHF_2-CF=CHF	Entgegen
R-1234ye(Z)	CHF_2-CF=CHF	Zusammen
R-1234ze(E)	CF_3-CH=CHF	Entgegen
R-1234ze(Z)	CF_3-CH=CHF	Zusammen
R-1234yf	CF_3-CF=CH_2	

A.4 Example 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 Figures A.1 and A.2. "E" for *Entgegen* is similar to trans, where priority atoms or groups are across the double bond from each other. "Z" for *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, I > Br > Cl > F > O > C > 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.

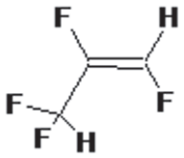


Figure A.1 — 1(E)-1,2,3,3-tetrafluoroprop-1-ene, or HFO-1234ye(E)

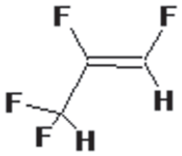


Figure A.2 — 1(Z)-1,2,3,3-tetrafluoroprop-1-ene, or HFO-1234ye(Z)

Annex B
(normative)

Details of testing for flammability and fractionation analysis

B.1 Flammability testing

Flammability tests shall be conducted in accordance with ASTM E681. Assuming testing a material with a large quenching distance which might 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 34-2013. 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. Dry reconstituted air (less than 0,000 15 g of water vapour per gram of dry air) containing (21,0 ± 0,1) % O_2 shall be used as oxidant.. The absolute humidity of the air shall be less than 0,000 15g grams of water vapour per gram of dry air or (0,0 088 ± 0,0 005) g of water vapour per gram of dry air, which equates to 50 % relative humidity at 23,0°C and 101,3kPa, whichever gives the lowest LFL. The subtended arc shown in Figure B.1 of ANSI/ASHRAE Standard 34-2013 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.

NOTE For fluorocarbon molecules having a fluorine-to-hydrogen ratio higher than 1,0, their flammability increases as the water vapour increases. The test method as described in this International Standard requires two levels of humidity, an energetic ignition source, and a uniform mixture.

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 2 out of 3 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.

CAUTION — Flammability test procedures specified in this International Standard are modified procedures of an ASTM test which uses a glass flask as a test vessel. Extreme caution should be employed by test facilities to safeguard against personal injury and equipment damage. Vessels can explode during test. Combustion of refrigerants may 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.1.1 Test conditions

a) For single compound refrigerants, flammability tests shall be conducted at 60 °C and 101,3 kPa .

b) For refrigerant blends, flammability tests shall be conducted on the WCF and WCFF at 60,0 °C and 101,3 kPa . The WCFF shall be determined by the method specified in 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 101,3 kPa to determine the LFL. For refrigerant blends, these tests shall be conducted on the WCF and the WCFF.

B.1.2 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.1.3 The mass fraction formulation of the tested blend shall be verified through gas chromatography to a tolerance of ±0,5 % mass fraction or one fourth of the composition tolerance range, whichever is smaller.

B.1.4 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 after 60 s of stirrer deactivation.

B.1.5 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 shorter spark duration but at least 0,2 s.

B.1.6 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.1.7 **Criterion for determining flame propagation**: a refrigerant/air concentration shall be considered flammable for flammability classification under this International Standard 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.1.8 **Flammability test data required**: applications shall include test results for a) to h) listed below. Applications 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: ±0,1 % mass fraction.

b) Flammability test temperature: ±0,5 K.

c) Fractionation or leak test temperature: ±0,1 K.

d) Test pressure: ±0,7 kPa.

e) Humidity: ±0,000 5 g of water vapour per gram of dry air.

f) Refrigerant/air concentration: ±0,2 % volume fraction.

g) Spark duration: ±0,05 s.

h) Flame propagation angle measured from the point of ignition to the walls of the flask: ±0,087 rad [±5,0° (degrees)].

B.2 Fractionation analysis

B.2.1 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 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 The mass fraction formulation of the tested blend shall be verified through gas chromatography to a tolerance of ±0,5 % mass fraction or one fourth of the composition tolerance, whichever is smaller.

B.2.4 **Leakage testing**: 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.2.4.1 **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 °C, and then shall be vapour leaked, at a rate that maintains the temperature of the liquid constant within 0,5 °C and prevents any liquid from escaping. Tests shall be conducted at the following temperatures.

a) 60 °C.

b) −40 °C or the bubble point at atmospheric pressure plus 10 °C, whichever is warmer. Tests shall be conducted at the bubble point plus 10 °C if the bubble point is > −50 °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 °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 loss 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.2.4.2 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 °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 °C, whichever is warmer. Tests shall be conducted at the bubble point plus 10 °C if the bubble point is > −50 °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 instead 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 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 loss 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 (±0,10 K);

b) tabulated liquid and vapour compositions at each leaked increment (±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
(informative)

Method of test for burning velocity measurement of flammable gases

C.1 General

The test method is based on:

a) the initiation of the combustion of the gas, or blends of gases, in a homogeneous mixture with air contained in a vertical cylindrical tube,

b) the observation and the recording of the flame propagation.

The burning velocity is a function of the flammable gas concentration in the total mixture with air. The burning velocity reaches a maximum in the vicinity of the stoichiometric concentration.

This test method involves the use of hazardous substances and therefore requires, for a safe handling and testing, the knowledge of safety parameters and prevention measures. These measures shall be the user's responsibility. However, general safety precautions are given in C.6.

C.2 Principle of the test method

The test method consists of initiating the combustion of a homogeneous mixture of a flammable gas (or a flammable mixture of gases) and air, contained in a vertical tube opened at the lower ignition end, and propagating a flame upwardly to the upper closed end; see Figure C.1. In the early stages of this propagation, there is a phase of uniform movement during which the shape and the size of the flame are constant.

Taking into account the mass and species balance through the flame front, the burning velocity, S_u, is calculated from the knowledge of the flame propagation velocity, S_s, in the tube and the ratio of the flame front area to its base cross-sectional area.

The volume of burned gas per second and per unit area, or the burning velocity, S_u, is obtained by dividing the mixture volume which is consumed per second, at the test temperature and pressure, by the flame surface area, A_f (the subscript "f" denotes the flame). The volume consumption of the mixture per second is the volume swept by a cross-sectional area of the flame base, a_f, with a velocity equal to the flame propagation velocity S_s. Formula C.1 is used to determine volume consumption.

$$S_u = S_s \times \frac{a_f}{A_f} \tag{C.1}$$

where

a_f is the cross-sectional area of the flame base;

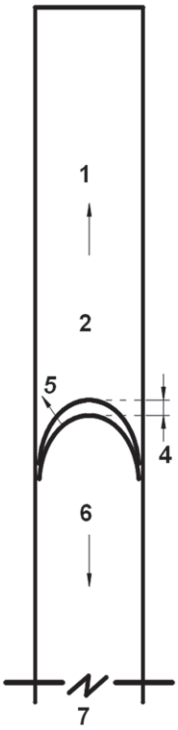
A_f is the flame surface area;

S_s is the flame propagation velocity;

S_u is the burning velocity.

NOTE The cross-sectional area of the flame base is equal to the tube cross section reduced by the quenching area (the area between the edge of the flame and the tube wall).

At a given temperature and pressure, the burning velocity is only a function of the type of flammable substance and its concentration with the oxidant and is dependent to a limited extent on the experimental apparatus.



Key

1	direction of flame propagation	5	S_u
2	unburned mixture	6	burned gas
3	flame front displacement	7	ignition
4	dx		

Figure C.1 — Schematic of the flame propagation in a vertical tube

C.3 Measurements

C.3.1 General

The measurement of the burning velocity requires the knowledge of the following three parameters of Formula C.1:

a) the flame propagation velocity;

b) the flame front area;

c) the cross-sectional area of the flame base.

C.3.2 Flame propagation velocity

The flame propagation velocity in the tube is required for the measurement of the burning velocity. As a condition to the derivation Formula C.1, only parts of uniform flame propagation shall be considered in the measurements (constant S_S).

The linear propagation velocity of the flame is obtained from the direct measurement of the flame front displacement determined by two successive images with a known time interval (30 Hz to 50 Hz) of the camera acquisition frequency. More than one succession of images shall be used to check that the flame propagation is uniform. An appropriate image treatment might be necessary in order to enhance the flame front shape and to locate on both images an identical luminous spot (pixels with equal brightness level) that corresponds to the same location on the front and deduce the flame front displacement. This procedure is proved necessary with low luminosity flames since any uncertainty in the flame front displacement leads to an uncertainty in the flame propagation velocity and thus on the burning velocity.

C.3.3 Flame front area

The flame front shape cannot be generated by the revolution of a parabola nor by the approximation by an ellipsoid segment, even though in many cases this shape is symmetrical. An accurate method is needed to calculate the flame front area A_f. For an upward propagation, the flame usually shows a symmetrical front surface referred to the tube axis. For a uniform propagation, the shape of the flame front remains constant. Fast moving flames are almost hemispherical, the slower flames are somewhat elongated.

C.7 describes a mathematical and geometrical model to calculate the flame front area. In summary, the flame front profile is marked with fitting points (20 to 40 fitting points) then divided into two or more horizontal sections. The fitting points shall be selected on the rim of the most luminous zone on the flame front (the outer layer towards the unburned gas). For each section a polynomial fit equation of appropriate order is made in order to give the best fit curve to the points selected on that section. The best fit gives the minimum deviation of the fit curve to the fitting experimental points. The area of each section is then calculated separately by dividing it into many small elementary sections. The area of each elementary section is then calculated from the assumption of a revolution shape.

C.3.4 Cross-sectional area of the flame base

The cross-sectional area, a_f, of the flame base shall be calculated from knowledge of the diameter d measured at the base of the flame as illustrated in C.7. In that case, use Formula (C.2):

$$a_f = \frac{pd^2}{4} \quad \text{(C.2)}$$

C.4 Test method and apparatus description

Measuring the burning velocity in a tube consists of

a) propagating a flame in a vertical transparent tube, opened at the lower ignition end, closed at the other upper end, and filled with the flammable mixture,

b) measuring the velocity of the flame propagating along the tube, and

c) recording the flame front area with a camera.

Measurements are performed at atmospheric pressure.

The test bench layout is shown in Figure C.2. The main elements of the bench are

— test tube,

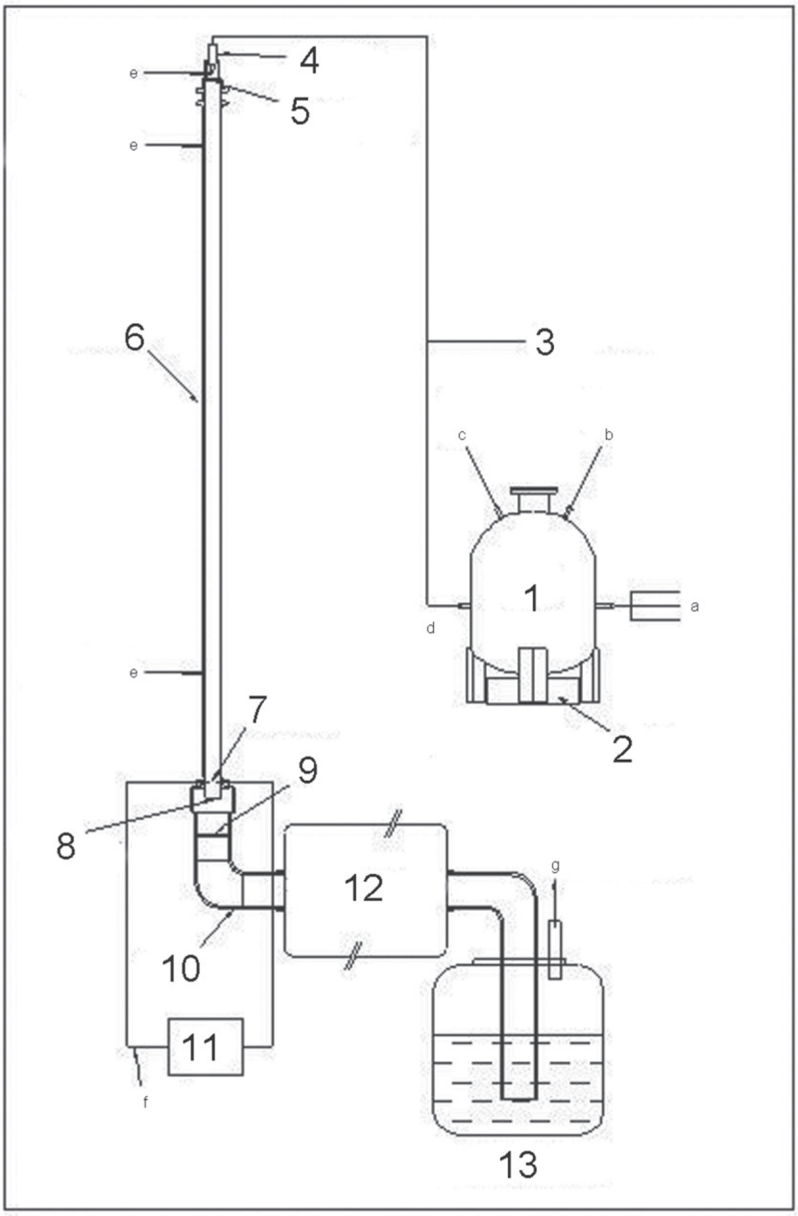
— mixing vessel,

— ignition system,

— camera,

— test temperature control, and

— gas treatment systems.



Key

1	mixing vessel
2	magnetic stirrer
3	purging gas line
4	tube inlet
5	quenching and smoothing screen
6	test tube
7	electrodes
8	fitting orifices
9	quenching screen
10	poly(vinyl chloride) pipe
11	igniter
12	gas expansion tank
13	collection tank with neutralizing solution
a	From gas supply tanks.
b	Pressure measurement.
c	To vacuum pump.
d	To inlet tube.
e	Temperature measurement.
f	Supply power to ignition.
g	Extraction to hood.

Figure C.2 — Schematic of the test bench

C.4.1 Gas handling and mixtures preparation

The gas mixture preparation is described in 6.1.3. If used, the scrubbing system described in C.4.5 should be disconnected so that the expansion volume is not filled with a flammable concentration. The constant composition blend is then caused to flow through the tube until the gas mixture displaces at least four times the air volume of the tube. Care should be taken to ensure that the gas mixture exiting the bottom of the tube is properly vented. Once the desired mixture has been achieved in the tube, the mixing vessel shall be isolated from the tube before ignition to prevent ignition of the gas in the vessel. It is good laboratory practice to measure the concentration of the gas mixture in the tube to ensure the methods employed adequately accomplish this objective. A paramagnetic oxygen analyser is effective for this determination.

It is recommended that all the components, connections and parts of the test bench be resistant to their use with corrosive gases, such as ammonia and copper, or other oxidation reactions. Stainless steel can be used or any other material identified to be adequate for use with the substances to test.

C.4.2 The test tube

The test tube shall be designed to ease the flame propagation with less possible disturbances, especially at the ignition level and the first stage of flame propagation; see Figure C.3. The design of the test tube should look into the following points:

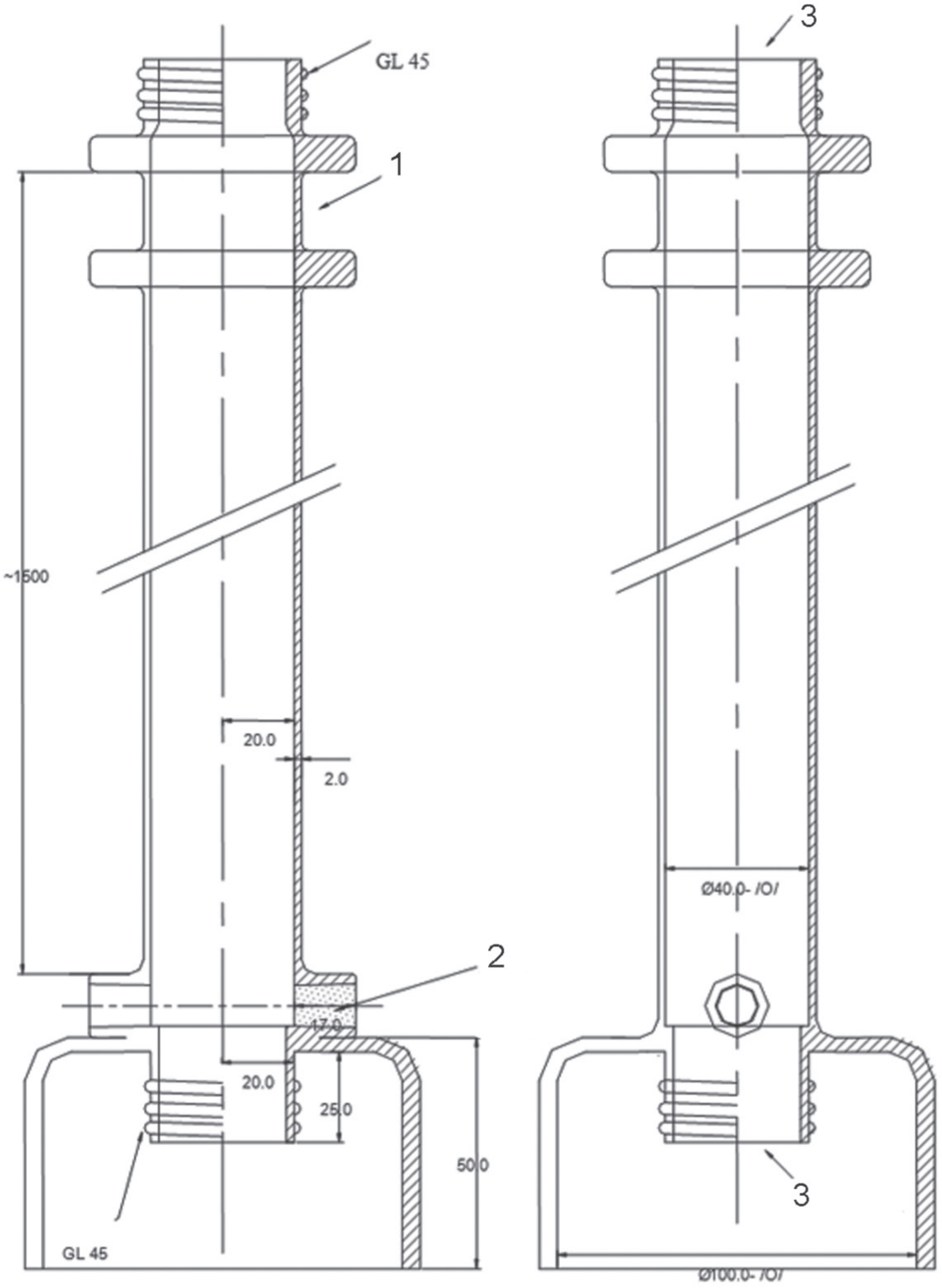
a) the ignition system, the quenching screen, and the damping orifice should be designed as close as possible to the outlet of the tube;

b) the outlet of the tube (at the lower end) should be designed to facilitate its connection to the extraction and gas treatment systems;

c) the tube should be fixed on a vertical support and at a level below the ignition system to prevent the fixing support from disturbing the flame propagation (excessive cooling) or any obstruction of the flame photography;

d) technical limitation with glass design and work should be considered as well.

Dimensions in millimetres



Key

1 fixing housing

2 RIN 10/19 housing for electrodes

3 inlet tube end

Figure C.3 — Test tube design and main dimensions

C.4.2.1 Dimensions

The tube is made of glass, 1,2 m long with a 40 mm internal diameter. The diameter has been chosen as a compromise between narrower tubes that increase the quenching effect but allow more stable propagation regimes, and larger tubes in which the losses to the walls are smaller but associated with an increase of instabilities.[20][21] The choice of the 40 mm diameter has been shown[22] to be the most convenient for measurement of burning velocities below 40 cm/s. It withstands a pressure of 100 kPa above the atmospheric pressure even if the overpressure is very limited, the bottom end of the tube being the open end.

NOTE Unstable regimes are frequent with fast propagating flames; see C.7.3. The tube length is based on dimensions from previous research. It is believed, however, that any great change in that length affects the flame propagation regimes and its stability only when working with high burning velocity compounds.

C.4.2.2 Position

The tube is placed in a vertical position to reduce possible deformations of the flame front from convection effect and to ensure a more symmetrical shape. In this position the flame propagates upwardly, the ignition occurring at the lower end of the tube.

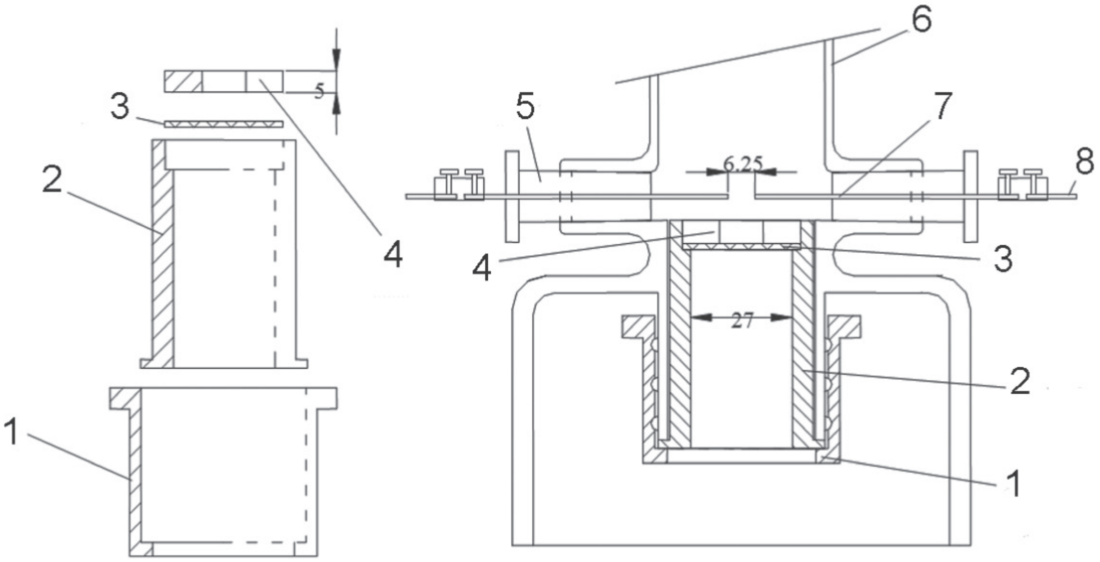
C.4.2.3 Tube ends

The bottom end of the tube is opened to the atmosphere. At this end are located the ignition system and the damping orifices. A GL45 cap can be used to maintain the system in place (see Figures C.4 and C.5). With harmful components present in the combustion products (toxic or corrosive, e.g. HF, HCl, NH_3), the lower end is connected to a gas post-treatment system (see C.4.6). This design does not allow excessive pressure build-up and the combustion products can freely exit the tube or expand in a 125 l tank if the gas treatment system is used.

The upper end of the tube is connected to the mixing vessel. Out from mixing vessel the mixture flows into the tube and out of its bottom end. A GL45 cap can be used to fix the inlet system. This end shall be closed before the ignition and until the end of flame propagation.

C.4.2.4 Interchangeable damping orifices

The flame propagation velocity and the flame shape vary with the type of flammable substance and the composition of its mixture with the oxidant. Adjusting the exit diameter at the lower open end by insertion of calibrated orifices helps the stabilization of the flame front shape by reducing the instabilities and damping the acoustic effects,[23][24][25][26] and therefore helps to reproduce a better shape of the flame front. The diameters of the damping orifices for a tube of 40 mm internal diameter vary from 9 mm to 11 mm (see Reference [26] for detailed calculation). The damping orifices are necessary only with relatively high burning velocities (i.e. higher than 25 cm/s) and typically associated with rich concentration mixtures.



Key

1	cap for GL 45 tip	5	RIN 10/19 polytetrafluoroethylene (PTFE) stopper
2	polytetrafluoroethylene (PTFE) body	6	test tube
3	quenching screen	7	1 mm diameter electrode
4	polytetrafluoroethylene (PTFE) fitting orifice	8	power supply connection

Figure C.4 — Drawing of the lower end of the tube showing the ignition electrodes and the damping (fitting) orifice

C.4.2.5 Flame quenching

Quenching screens are mounted at both ends of the tube, resistant to the reaction with HF and NH_3, to prevent any hazard to the surroundings. The quenching screens shall have a mesh size of $1^{+0,5}_{-0,1}$ mm (HCs have a quenching distance of around 2 mm which increases when decreasing burning velocity).

C.4.2.6 Tube glass type

The spectral emissions of most flames are presumed to be in the range of 250 nm to 600 nm. To prevent excessive losses, it is important to compare the glass transmission profiles before selecting the type of glass (e.g. silica glass, borosilicate glass).

C.4.2.7 Tube purging with test mixture

The test tube shall be purged by the mixture under test with a continuous flow from the mixing vessel with an equivalent volume flow rate which represents at least 13 times the internal tube volume. The gas mixture shall enter the upper end of the tube and exit from its lower end. The lower end can be closed after purging to avoid any possible concentration variation by dilution in the neighbourhood of the electrodes. This end is opened to the atmosphere just before ignition.

C.4.2.8 Tube etching

The presence of substances such as hydrogen fluoride (HF) or hydrogen chloride (HCl) with water residues in the combustion products of HFCs or HCFCs results in tube etching so that after several tests (30 to 50 depending on the cleaning process) the tube turns opaque with an almost white colour (see Figure C.5).

For this reason, the tube should be purged immediately after the end of the flame propagation with a stream of dry nitrogen and afterwards a wet wiper can be introduced inside the tube to clear all deposits on the inner wall. A stream of nitrogen can be again circulated inside the tube to remove water deposits from the wiper.

With this cleaning technique it is possible to use the same tube for a larger number of tests before the etching effect becomes noticeable.

Figure C.5 — Tube etching due to hydrogen fluoride

C.4.3 Ignition

The ignition source can affect the flammability limit results or even the flame propagation regime. Analyses of spark ignition have been made by many researchers (Reference [27] gives a survey) and deal with the electrodes arrangement, type (flange electrodes for instance), material and size, the gap, the spark duration and the breakdown voltage as well as the effect of these on the minimum ignition energy.

The ignition system described in this test method has the same characteristics as the ignition system used in the ASTM E681 flammability test method in terms of the electrode dimensions, the gap distance, the ignition time and the power supply. This similarity helps to bring together the flammability testing made with the tube method and that made by the ASTM method.

NOTE These ignition specifications are also very similar to those specified in DIN 51649-1 (which is meant by the flammability limits).[28]

C.4.3.1 Ignition type

The mixture is ignited with an electrical spark produced by two electrodes.

C.4.3.2 Positioning

The ignition occurs at the bottom end of the tube. The electrodes are fixed diametrically opposite on the tube, centred on its axis and positioned 5 mm to 10 mm above the upper surface of the interchangeable orifices. The electrodes are fixed using RIN 10/19 PTFE stoppers lodged in specially conceived RIN 10/19 housing (see Figure C.4).

C.4.3.3 Electrodes

The electrodes are made of tungsten with 1 mm diameter. The gap between the electrodes is 6,4 mm. When necessary, a special calibrating cylinder can be inserted inside the tube and in-between the electrodes in order to verify their centricity and to ensure a correct gap distance.

To ensure good ignition conditions, especially near the lower and upper propagation limits, the electrodes shall be repeatedly cleaned of any deposit.

C.4.3.4 Power supply

Power to the ignition electrodes shall be supplied by the secondary of a transformer with an output of 15 kV, 30 mA. Usually, such high voltage is not required except with compounds having a high breakdown potential. The power supply system is adequately connected to the electrodes to avoid short circuits and overheating at weak connection points.

C.4.3.5 Ignition time

The ignition time shall be set at (0,3 ± 0,05) s by adjusting the spark duration with a timer. This time duration has been proved to be the most appropriate for flammability limits measurements.[9]

Ignition should not be made immediately after filling the tube with the corresponding mixture, but 5 s to 10 s later, permitting the turbulence to cease in the tube.

NOTE The excessive energy release from this ignition system might be responsible for emitting waves inducing turbulence in the flame front and the mixture ahead of it.

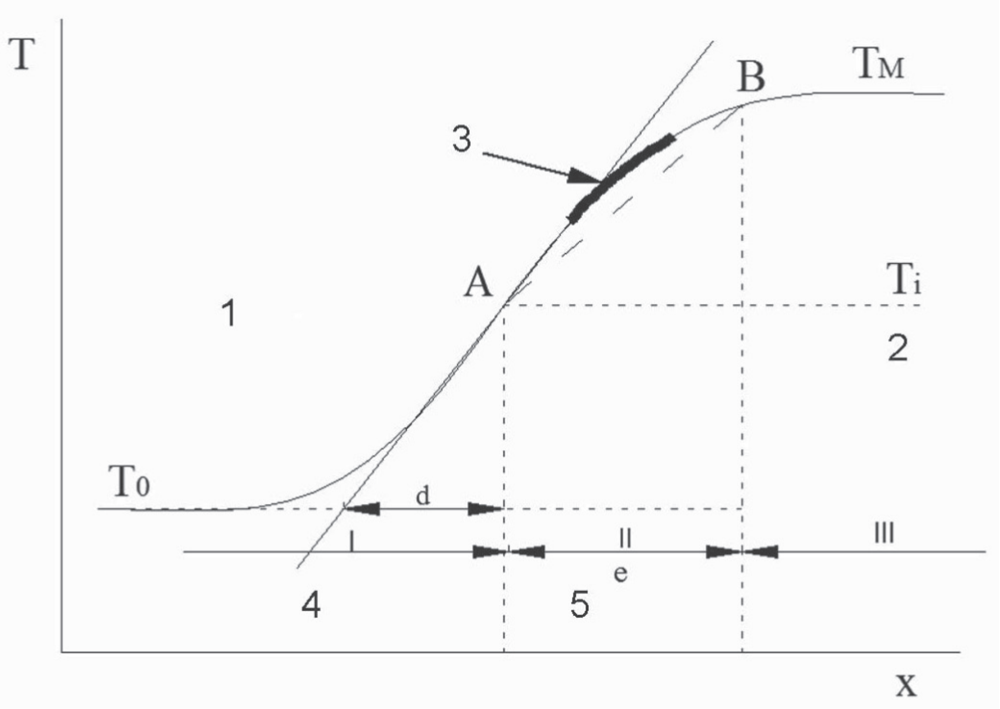
C.4.4 Flame front visualization

Direct photography is used to record the flame front images. These images are used for the calculation of the flame propagation velocity as well as its surface area.

C.4.4.1 Luminous zone and direct photography

The burning velocity measurement Formula (C.1) is based on the calculation of the flame front area at the preheat zone layer. With direct photography, the luminous zones of the flame are revealed. Therefore, any measurement made with this photography technique shall be based on the zone of the flame of most intense illumination. This zone corresponds to the region of the flame between the point whose temperature is equal to the ignition temperature and the point at the end of reaction (see Figure C.6). The relative uncertainty in the burning velocity assessed with the flame front area calculation based on flame profiles from direct photography is 6,5 %.

NOTE The 6,5 % relative uncertainty can be reduced and the correct surface position could be better approached if the profile of the outer edge of the luminous zone is shifted outwards by a distance equivalent to the luminous zone width.



Key

1 unburned gas
2 burned gas
3 luminous zone
4 pre-heat zone
5 reaction zone

Figure C.6 — Temperature profile along a combustion flame and luminous zone

C.4.4.2 Flame emission spectra

The spectra peaks from combustion depend on the type of substance combusted and the radicals formed such as OH, HCO, CH, C_2 and C_3. From a qualitative point of view, it can be stated that the typical peaks for maximum emission, and even sometimes a high level continuum, are in the range of 250 nm to 600 nm for HC and HFC flames.

C.4.4.3 Acquisition camera

The use of a digital camera is recommended to visualize the flame propagation. The flame front images should be recorded and saved for further treatment (flame propagation velocity measurement and flame front area calculation).

When identifying the camera to run the tests, the characteristics of exposure time and acquisition rate should be selected as a function of the velocity range being measured. With very fast flames, a high acquisition rate and small exposure time are needed (i.e. <1 ms). The spectral response of the camera shall be also taken into account and the higher efficiency of the quantum efficiency curve shall cover the range of typical wavelength of the flames being visualized.

NOTE A set of adjustments and different operating modes, such as the resolution, image enhancements, image rate, exposure time, number of frames during record, pre-/post-trigger and parameters for image output, performed via an appropriate interface, can help in adapting the images to the type of flame front being recorded. A set of lenses can also be used to zoom and focus the optimized photography frame.

C.4.4.4 Exposure time

Setting the exposure time is necessary before starting the photography of the flame propagation to best reproduce the flame front shape and increase the precision of its area measurement.

Since there is no defined relationship between the flame propagation velocity and its more or less luminous aspect, for fast and low luminous flames the tester has to find a compromise for setting the exposure time. A higher exposure time compensates the low luminosity but results in an imprecise shape of the flame front due to its displacement during the exposure time.

For measurements around the stoichiometry, the recommended exposure times are of 1 ms or less. This value is determined by practical experience and depends on the camera.

C.4.4.5 Positioning

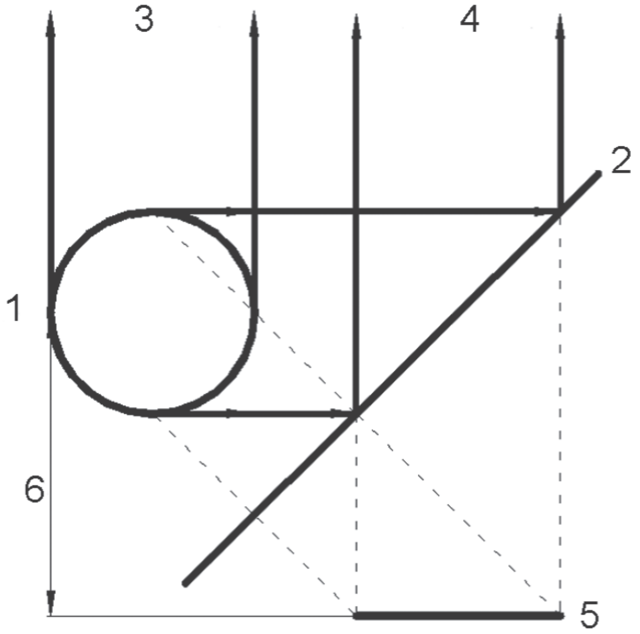
The camera recording field shall be adjusted to the appropriate position and height of the tube where the flame movement is known to be uniform. Only images taken at the same level of the lens axis shall be used to calculate the flame front area and reduce the imprecision on the flame front dimensions.

C.4.4.6 Scaling and optical distortion

Scaling of the flame images to the real flame front dimensions can be achieved by taking a photo of a graduated ruler placed along the tube in order that the graduations coincide with a layer crossing the centre of the tube and at right angles to the camera axis.

NOTE The optical deformation due to the tube wall geometry is negligible.

A mirror at 45° is placed beside the tube in order to identify the irregularities of the flame front surface and to increase the accuracy of the tests by ensuring the correct assumptions for the flame front area calculation. With the camera facing both the tube and the mirror, recorded images give both the front view and the side view of the flame front (see Figure C.7). Note that the plan in which is located the mirror image is placed behind that of the direct photography. If used for calculation these images shall be scaled to the same vertical layer crossing the centre of the tube and at right angles to the camera axis.



Key

1	tube	4	side view image beam
2	mirror	5	actual side view image position
3	face view image beam	6	displacement

Figure C.7 — Schematic of the face and side view image as received by the camera

C.4.4.7 Resolution of the flame images

The essential uncertainty in the measurement of the burning velocity with the tube method is related to the image resolution for the flame propagation velocity, the scaling factor and the flame front area. An increase in the resolution provides more accurate results, but to the extent where the points fitting on the flame front image becomes independent of the pixels of small dimensions.

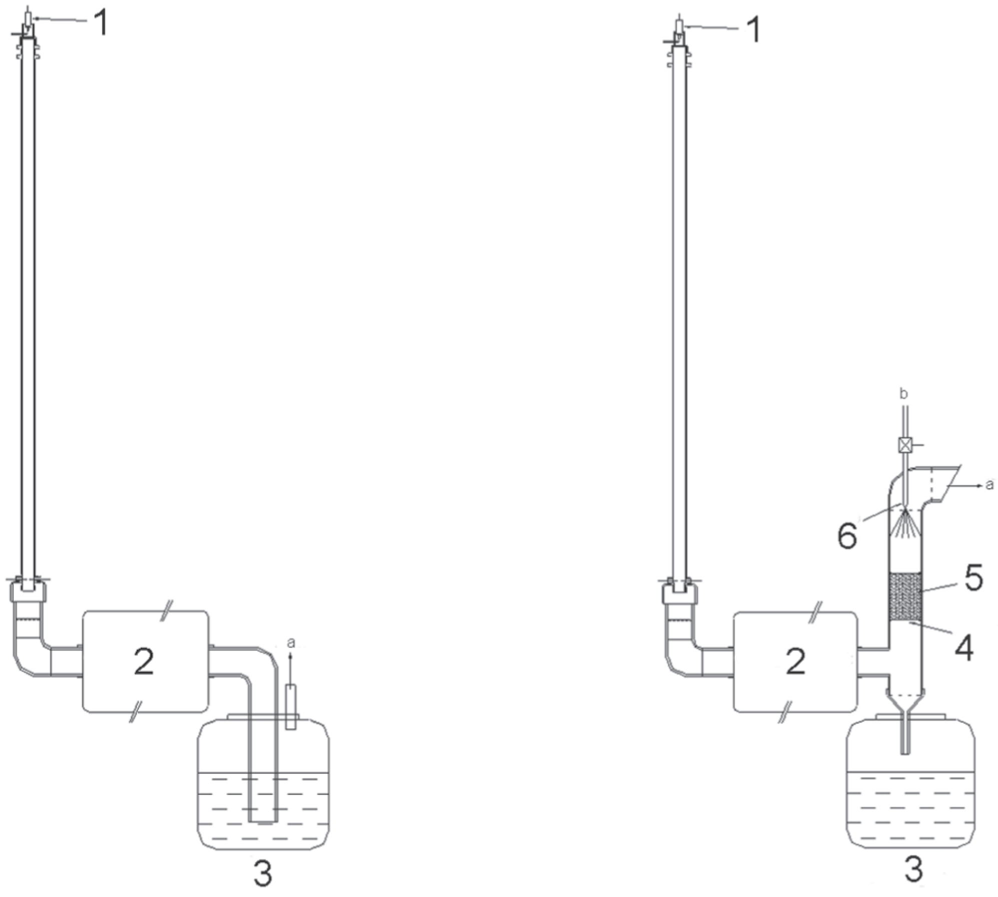
C.4.5 Purge, exhaust and gas treatment systems

The test apparatus shall be cleaned thoroughly after each test to remove the remaining combustion products and effluents from the previous test and to make sure that the combustion products shall not harm the personnel or damage the environment. An appropriate treatment process of the combustion products, especially with fluorinated gases, shall be put in place: the extraction of the combustion products shall be performed rapidly at the end of the test in order to neutralize the HF or HCl, which in some cases constitutes more than 30 % of the combustion products, and reduce the corrosion of the test tube (a small amount of moisture makes it very corrosive). For this purpose an ad hoc treatment system and exhaust gas cleanup is designed and installed at the outlet of the test apparatus, permitting the removal of the corrosive substances by splashing the exhaust gas into a basic water solution (e.g. NaOH). The treatment system also includes an expansion tank connected between the gas treatment system and the lower end of the tube to simulate a constant pressure expansion condition (see Figure C.8). An extraction fan evacuates the combustion products from the tube, through the expansion tank and the water solution and then the clean gas to the hood.

If needed, a water scrubbing system can be used instead of a splashing system. In that case a cone nozzle can be used for example to spray water onto the upward exhaust gas flow. The acid water is collected at the bottom and drained into a larger tank filled with a basic water solution to neutralize the acid water.

The water solution tank should be emptied regularly and the acidity of the water solution checked to guarantee safe handling.

NOTE If necessary, two treatment systems can be placed in series to achieve a more complete removal.



a) With splashing **b) With scrubbing**

Key

1	tube inlet	4	support screen
2	gas expansion tank	5	scrubber
3	collection tank with neutralizing solution	6	nozzle
a	Extraction to hood.		
b	Water supply.		

Figure C.8 — Gas treatment system

C.4.6 Test temperature setting

Test temperature of 23 °C is simply achieved by controlling the temperature in the test room. Since the flame propagation is temperature sensitive, the temperature gradient along the tube should be minimized, e.g. to less than 1 °C. This may be achieved by an appropriate circulation and control of a temperature controlled air stream.

C.4.7 Experimental protocol

The following protocol is applied for running the tests when the partial pressure technique is used to prepare the mixtures.

a) The following items shall be checked before starting a new test:

   1) recording the reference scale of the camera to that of the real flame dimension (pixels/m, or equivalent);

   2) clean the tube by dry gas purging (air or nitrogen);

   3) check the electrodes gap distance and centricity;

   4) select the appropriate exit orifice diameter.

b) The mixing vessel and all connecting pipes and tubes shall be first evacuated to a pressure of 10 Pa abs or less.

c) The mixing vessel shall be then filled with the different mixture components, each at its corresponding partial pressure. The connections shall be evacuated each time a new gas is introduced into the mixing vessel. The magnetic stirrer should be turned on at the start of the process and for at least 5 min after the end of the filling process.

d) The mixture can be then allowed to leave the mixing vessel, circulate through the tube, out from its lower exit end and to the extraction hood. An equivalent volume of at least 13 times the internal volume of the tube is circulated.

e) The upper end shall be closed first and then the lower end immediately after it to prevent any possible dilution or concentration changing within the electrodes region.

f) 5 s to 10 s should be given for the mixture inside the tube to become quiescent.

g) The lower end shall be opened gently to avoid any perturbation or concentration changes around the ignition region, and then ignition is made. Just before ignition, the camera should be activated and the images are recorded.

h) After the end of the flame propagation, quenched at the upper end of the tube, the combustion products are driven out by a stream of nitrogen or air circulated inside the tube. In the case of harmful combustion products, the ad hoc gas treatment system shall be installed and used.

C.5 Evaluation and expression of results

$$S_{\mathrm{u}} = S_{\mathrm{u,max}} - a(\Phi - \Phi_{\mathrm{max}})^2 \tag{C.4}$$

where

$S_{\mathrm{u,max}}$ is the maximum burning velocity from the second-order polynomial fit to the experimental points;

Φ_{max} is the equivalence ratio at the maximum burning velocity;

a is a fit constant.

In few cases, Formula (C.4) does not achieve the best fit to the burning velocity experimental results. Other adequate fitting equations should then be elaborated. The experimental points can also be split into two parts and for each a separate fitting equation can be used.

NOTE In general, the maximum burning velocity is met at an equivalence ratio between 1,00 and 1,15.

C.5.1 Uncertainty

C.5.1.1 Uncertainty in the burning velocity

The total relative uncertainty of the burning velocity measurements as described in this International Standard is estimated between 7 % and 10 % and is due

a) primarily to uncertainties in the flame front area calculation (65 % of the total uncertainty), and

b) the flame propagation speed measurement (35 % of the total uncertainty).

C.5.1.2 Uncertainty estimation of concentrations

The concentrations of the mixtures as prepared with the partial pressure method are subjected to an uncertainty arising mainly from:

a) pressure transducer measurement;

b) ideal gas law used to derive the densities from the pressure and temperature. With air being the major component in the mixtures, the mixture state at pressures between 300 kPa and 400 kPa abs is not very far from the ideal state. In that case the relative uncertainty in the density is evaluated to 2 % whereas it can be neglected for pressures below 100 kPa abs,

NOTE The greater part of the uncertainty in the concentration arises from the ideal gas law assumption. For concentrations as high as 30 % volume fraction, the absolute uncertainty can be estimated at 0,6 % volume fraction or 2 % relative. For concentrations as low as 2 % volume fraction, the absolute uncertainty can be estimated at 0,08 % volume fraction and the relative uncertainty at 4 %.

The uncertainties in the burning velocity measurements and the mixture concentrations shall be determined specifically for each test bench.

C.6 Safety precautions

C.6.1 The safety recommendations are made for a proportion of oxygen in the air no higher than 21 % volume fraction.

C.6.2 For high burning velocities (>30 cm/s), it is recommended to make the tests starting from the lowest LFL of the components and gradually increasing the concentration. This is appropriate to avoid explosions with fast propagating flames at concentrations near the stoichiometry. An excessive restriction of the exit end with the interchangeable orifices shall be avoided.

C.6.3 Appropriate protection equipment shall be used by the test bench user (e.g. gloves, eye and head protection, etc.).

C.6.4 The ad hoc gas treatment system shall be manipulated with caution because of its content of corrosive substances. The treatment system shall be sealed and an extraction fan should be used to avoid any inhalation of the combustion products.

C.6.5 The high voltage ignition system, connections and electrodes should be handled with care and protected to prevent any direct contact. For safety reasons, potential ignition sources other than that intended for the testing should be avoided (e.g. switches, electrical contacts).

C.6.6 Quenching screens shall be mounted on both ends of the test tube. An additional quenching screen shall be placed at the entrance to the expansion volume to prevent any ignition hazard within that volume.

C.7 Overview on flame shape, propagation regimes and stability

C.7.1 Flame shape

When considering a combustion wave propagating from the open to the closed end of the tube, the unburned gas ahead of the wave is contained by the tube wall so that it forms a stationary column. The thermal expansion within the wave generates a continuous flow of burned gas towards the open end. The main parameters contributing in the establishment of the flame front shape are the following:

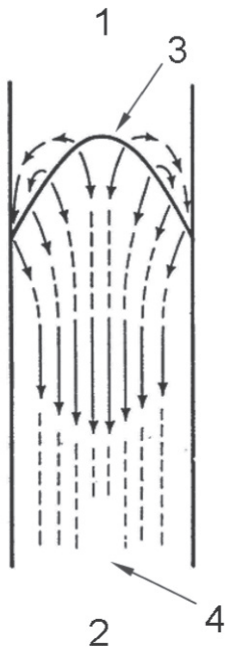
a) viscous drag responsible for flow retarding at the wall and acceleration in the centre of the tube (higher pressure thrust in the centre than near the wall);

b) unburned gas flow away from the flame front at the centre and towards it at the edges (the unburned gas ahead of the flame is pushed towards a closed end);

c) convection effect of burned gas resulting in an elongated front with slower propagating flames whereas the front takes an almost spherical shape with fast propagating flames;

d) constant burning rate in a direction normal to the flame front.

The balance between all the above-mentioned effects hence seems to be conditional for maintaining constant the stability of the flame front during uniform movement (see Figure C.9).



Key

1 closed end

2 open end

3 unburned gas

4 burned gas

Figure C.9 — Direction of flow and particle velocity for laminar combustion wave propagation from open to closed end of tube

C.7.2 Flame propagation regimes

With high burning velocities, the propagation usually develops in three distinct stages or regimes with two possible types of movements. The three stages can be distinguished either by flame structure or the amplitude of pressure and flame oscillations as well.

The flame movement consists of one of the two following movements:

a) uniform movement;

b) vibratory movement.

The regime of flame propagation can develop into the following respective stages.

- After ignition, the flame propagates smoothly across the first part (first stage) of the tube at a uniform velocity which depends on the mixture and the tube length.
- An oscillatory motion of the flame can superimpose after the first stage. These oscillations begin with the appearance of a cellular structure in the flame front. The onset of oscillation and vibrations during propagation is the result of a coupling between flame and pressure oscillations in the gas.
- As the flame progresses, the tube becomes increasingly filled by hot combustion products and hence the basic frequency of the oscillation rises. The flame front can be subject to violent reciprocating motions and would accelerate steadily until the appearance of the turbulent propagation regime, leading to a large instability level, which persists until combustion is complete.

The termination of the uniform movement by a vibratory motion of flame always occurs when ignition is done at the opened end of the tube, the only exception being with slow burning mixtures, in which combustion may proceed at a uniform rate over a major part of the tube length.

NOTE 1 Measurements in a 40 mm tube of burning velocities below 23 cm/s[26] showed almost no flame acceleration. Compounds having burning velocities below 10 cm/s have been witnessed to propagate with velocities not exceeding 25 cm/s.

NOTE 2 Cellular form of flames is associated with high propagation velocity flames – high burning velocities – and rich mixtures. The flame front area of cellular flame cannot be measured with acceptable precision. For this reason the tube method is limited to comparatively low burning velocity measurements.

C.7.3 Flame stability in tubes

The main and possible reasons behind turbulence generation should be identified in order to understand particular behaviours of flame propagation. In general, the turbulence of a premixed flame can be attributed to one of the following reasons:

a) the initial gas flow turbulence in the flammable mixture can induce disturbances in the flame front shape and behaviour;

b) non-uniformity of the flammable mixture concentration, pressure and temperature. In that case the flame propagates in a mixture in which conditions are changing and thus its propagation is affected, too;

c) gas flow turbulence in the flammable mixture at the shear-flow region between the wall or the obstacles and the gas flow induced by propagation of the flame;

d) in an accelerating flow field, gas flow turbulence is generated near the flame front;

e) flame front disturbances caused by thermal and mass diffusion mechanisms;

f) interaction of the flame front with the acoustic waves emitted by the flame propagation.

The stage of uniform movement of the flame can start when the disturbances in the unburned mixture are damped and the flame propagates in a medium at rest.

Particular attention should be given to acoustic instabilities identified with fast propagating flames. As a potential turbulence generator, acoustic instabilities turn out to be the most difficult to eliminate but could be controlled by a proper design. Damping of acoustic vibrations can be achieved by inducing a resistance to the flow of burned gas to increase the corresponding pressure above a certain level.[8] This can be done by reducing the opened end of the tube by means of an orifice. This reduction will increase the uniform movement of the flame.

The acoustic instabilities can hence be attenuated by reducing the opened end of the tube by means of an orifice whose diameter is defined by Formula (C.5):

$$\frac{d}{d_e} = \left(1 + \frac{C_b}{(E-1)S_s}\right)^{1/4} \tag{C.5}$$

where

d is the internal diameter of the tube (m);

d_e is the diameter of the orifice (m);

C_b is the speed of sound in the burned gas (m/s);

E is the expansion ratio (i.e. ratio of the unburned and burned gas densities);

S_s is the flame propagation speed in the tube (m/s).

This operation is necessary only with fast propagating flames, as experienced during experimental tests, and high burning velocities. However, the acoustic damping can be insufficient to eliminate the fast flame disturbances in its initial propagation phase. The disturbances in the unburned mixture ahead of the flame shall be prevented as well. This could be achieved by placing fibreglass pads some distance from the closed downstream end of the tube.

C.7.4 Observations of flames in tubes

a) The fastest flames lose their uniform motion after some distance, and the slower flames travel a longer distance before the flame front loses its regular shape. The motion becomes non-uniform because of a vibration motion, which is sometimes so severe in the slower burning mixtures that the flame is extinguished.

b) The faster flames remain upright until the non-uniform motion. The slower flames are sometimes slanting during the uniform motion. The intermediate velocity flames (particularly on the rich side of the concentrations) seem to be able to adopt either an upright or a slanting form, or the flame may change gradually or abruptly from the upright to the slanting form. The point where this change occurs seems to be quite arbitrary, and some flames which can adopt the slanting form remain upright until the onset of the non-uniform motion. The slanting form seems to be the more stable, since the change never occurs in the reverse direction. Both forms of the motion seem to be quite uniform, with the result that the flame may have first a slow uniform velocity, followed by a faster uniform velocity, before the non-uniform motion starts.

c) Some flames can show some unusual behaviour from all the others corresponding mixtures. Those flames proceed rapidly, upright and emit considerably more light than the other observed flames, while expected to be rather slow and probably to adopt a slanting form. It is possible that this anomaly is connected in some way with the change in reaction mechanism noticed for some mixture compositions. The general structure of the flame might also appear to be different in some of these cases. There is no explanation for such exceptional flames, but it does seem that slight conditions can cause a marked change in flame velocity, and perhaps even in the mode of flame propagation in tubes.

C.7.5 Flame quenching in circular tubes

When a flame is propagating near a surface, effects on the flame configuration cannot be neglected. The flame appears to be quenched and to be standing a distance of few millimetres away from the wall. This distance is called the quenching distance. This quenching phenomenon is governed by three different mechanisms that can be summarized in the following:

a) heat conduction from the flame to the wall reduces the energy available to preheat the gas ahead of the flame;

b) absorption, by the wall, of active chemical species that are important in the chain of chemical reactions that create a continuous propagation;

c) viscous effects at the wall.

In most cases the first mechanism seems to be the most significant. This unavoidable effect of flame cooling by the tube wall lowers the apparent burning velocity obtained by this method below its value in free space.

The loss of heat to the wall cannot be eliminated entirely, but it is confined to the region behind the flame where high temperatures, high gas velocities and disruption of the boundary layer on the tube walls by the passage of the flame serve to increase the rate of heat transfer between the wall and the burned products. If the tube is closed at both ends, the heat loss would be noticed by a decrease in pressure, but in the current measurements the pressure is maintained by the surrounding atmosphere, and hence the cooling of the burned products has no influence on the progress of the flame.

One effect of this layer of unburned gas on the wall surface is to reduce the effective cross-sectional area of the tube. This reduction shall be taken into account for the correct measurement of the burning velocity, otherwise it will introduce an error. The level of this error is proportional to the ratio of tube diameter to flame area as can be deduced from Formula (C.1). It is therefore desirable to use a tube of a cross-sectional area as large as possible. But in practice, a critical size exists above which the flame surface becomes distorted by convection effects in the burnt products. Consequently for high velocity measurements, the tube diameter should probably not be larger than a certain critical diameter to avoid turbulent flame fronts. For slow burning mixtures, the tube diameter probably should not be less than a critical diameter to avoid excessive surface effects. A 40 mm internal diameter can achieve this compromise (see C.4.3.1).

C.7.6 Flame propagation velocity and tube diameter

The flame velocity of uniform propagation in a tube increases with increasing tube diameter.

Based on experimental results,[22] an equation is derived to estimate the flame propagation velocity at a level of burning velocity below 50 cm/s measured in a tube of diameter d between 25 mm and 60 mm.

$$S_\mathrm{s} = 1{,}66 S_\mathrm{u} + 0{,}18 d + 3{,}31 \tag{C.6}$$

where

S_s is the flame propagation speed (cm/s);

S_u is the burning velocity (cm/s);

d is the internal diameter of the tube (mm).

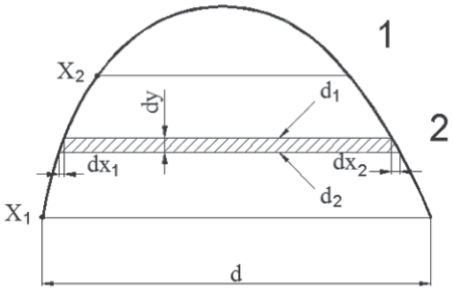
C.7.7 Flame area calculation

An accurate method is needed to calculate the flame front area, A_f. Even though in many cases the flame front shape is symmetrical, this shape cannot be generated by the revolution of a parabola nor by approximation by an ellipsoid segment. For an upward propagation, the flame shows a symmetrical front surface referred to the tube axis. For a uniform propagation, the shape of the flame front remains constant. Fast moving flames are almost hemispherical, and the slower flames are somewhat elongated.

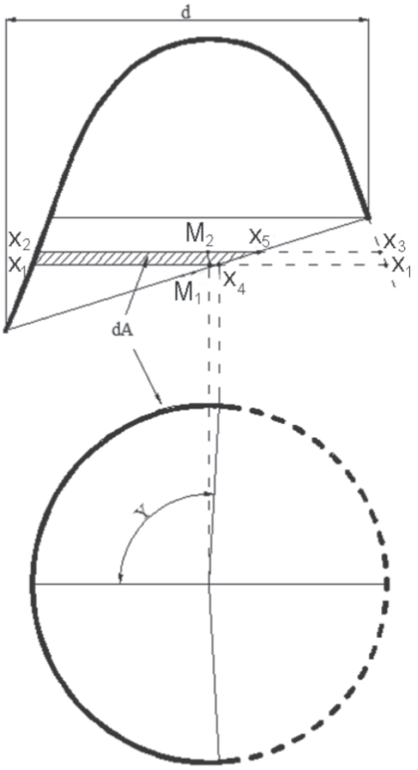
To measure A_f, the flame front profile shall be marked with fitting points (20 to 40 fitting points) then divided into two or more horizontal sections. The fitting points shall be selected on the rim of the most luminous zone on the flame front (the outer layer towards the unburned gas; see C.4.4.1). For each section a polynomial fit equation of appropriate order is made in order to give the best fit curve to the points selected on that section. The best fit is the one that gives the minimum deviation of the fit curve from the fitting points. Usually, polynomial equations of the 6° order and lower are sufficient to achieve the exact fitting. The area of each section is then calculated separately by dividing it into a large number of small elementary sections. The area of each elementary section is then calculated from the assumption of a revolution shape (a representation is illustrated in Figure C.10 a).

NOTE Because a section might reveal a different revolution axis than the others, the use of Simpson or Tchebitcheff integration formulae could not be used instead of the small partitions.

Since the lower edges of the flame front are not necessarily at the same level, the case of tipped flames, a special mathematical and geometrical means taking into account the level difference between the two edges are used to estimate the area of that part of the flame front (a representation is illustrated in Figure C.10 b). Tests with very tipped flames should not be used in the measurement of the flame area. Tipped flames are mostly seen on the rich side of the concentrations and rarely around the stoichiometry or even at the maximum burning velocity. In that case more than one measurement is repeated in order to have a better representation of the correct value. Usually the measurement that represents more than 5 % to 10 % difference from the average should not be considered.



a) Non-tipped



a) Tipped

Key

1 section 1

2 section 2

Figure C.10 — Elementary non-tipped and tipped section in flame front area calculation

A_f is obtained by summing all the surface areas of the sections:

$$A_\mathrm{f} = \sum_{\text{section}} A_i \tag{C.7}$$

With a non-tipped section, A_i is given by [see Figure C.10 a)] Formula (C.8):

$$A_i = \sum_{X_1}^{X_2} \left[\pi \left(\frac{d_1 + d_2}{4} \right) \left(\sqrt{(\mathrm{d}x_1)^2 + (\mathrm{d}y)^2} + \sqrt{(\mathrm{d}x_2)^2 + (\mathrm{d}y)^2} \right) \right] \tag{C.8}$$

With a tipped section, A_i can be estimated by [see Figure C.10 b)] Formula (C.9):

$$A_i = \sum \left[\left(Ar\cos\left(\frac{M_1 - x_4}{x_1 - M_1} \right) (x_1 - M_1) + Ar\cos\left(\frac{M_2 - x_5}{x_3 - M_2} \right) (x_3 - M_2) \right) \cdot \left(\sqrt{(x_2 - x_0)^2 + (\mathrm{d}y)^2} \right) \right] \tag{C.9}$$

where M_i are the segment midpoints.

Annex D
(normative)

Calculation of RCL and ATEL for blends

D.1 Calculation of RCL and ATEL for blends

The ATEL for a refrigerant blend shall be set as the lowest of the blend acute toxic concentration factors (TCFs). For the purpose of this annex, TCF a) refers to 8.1.1.2, TCF b) refers to 8.1.1.3, TCF c) refers to 8.1.1.4, and TCF d) refers to 8.1.1.5.

Each blend acute TCF quantity is calculated from the acute TCF values of its individual components, following the Additivity method for mixtures (see Reference [34]). The additivity method is especially applicable to materials of similar chemical properties, for example hydrocarbons or halogenated hydrocarbons.

The blend acute toxicity calculation shall be as given by Formula (D.1):

$$a_{\text{blend}} = \frac{1}{\frac{x_1}{a_1} + \frac{x_2}{a_2} + \cdots + \frac{x_n}{a_n}} \qquad \text{(D.1)}$$

where

a_{blend} is the blend mortality indicator;

a_n is the mortality indicator for component n in the blend (i.e. the 4-h LC_{50});

x_n is the mole fraction of component n.

In a similar fashion, blend cardiac sensitization indicator b_{blend} can be calculated from $1/\sum x_n/b_n$, where b_n is the cardiac sensitization indicator for component n in the blend (i.e. 100 % of the NOAEL, or if not determined, 80 % of the LOAEL), and from the mole fraction x_n of component n, and so forth for the acute TCFs a) to d).

Each acute TCF for a blend can be expressed in parts per million of substance in air by volume (ppm) if the acute TCFs for each component n are expressed in parts per million and x_n is expressed as the mole fraction of component n in the blend. (The TCF of each component shall be determined according to the priority indicated in Clause 7. Thus, the determining method for each component might not be consistent, such as 100 % of NOAEL of component A and 80 % of LOAEL of component B.)

D.2 To convert parts per million [ppm[1)]] to milligram per cubic metre (mg/m^3) for each component *n* at 25 °C

a_n in mg/m^3 = [a_n in ppm][relative molar mass of component n]/[24,5]

D.3 To convert milligram per cubic metre (mg/m^3) to parts per million (ppm) for each component *n* at 25 °C

a_n in ppm = [a_n in mg/m^3][24,5]/[relative molar mass of component n]

D.4 Example: ATEL calculation for R-410A (50 % mass fraction R-32/50 % mass fraction R-125)

R-410A composition, expressed in mole fraction, is (0,698 mol fraction R-32/0,302 mol fraction R-125):

$$a_{\text{blend}}\ \text{R-410A} = \frac{1}{\dfrac{0{,}698}{215\,000} + \dfrac{0{,}302}{218\,000}} \tag{D.2}$$

where

$a_{\text{R-32}}$ is the LC_{50} of R-32 or 760 000 ppm × 0,283 = 215 000 ppm;

$a_{\text{R-125}}$ is the LC_{50} of R-125 or 769 000 ppm × 0,283 = 218 000 ppm;

$a_{\text{R-410A}}$ is 216 000 ppm as the R-410A mortality indicator.

$$b_{\text{blend}}\ \text{R-410A} = \frac{1}{\dfrac{0{,}698}{200\,000} + \dfrac{0{,}302}{75\,000}} \tag{D.3}$$

Correct equation to _________1_________

0,698 + 0,302

350 000 75 000

where

$b_{\text{R-32}}$ is the cardiac sensitization indicator NOAEL for R-32 or 350 000 ppm;

$b_{\text{R-125}}$ is the cardiac sensitization indicator NOAEL for R-125 or 75 000 ppm (NOAEL);

$b_{\text{R-410A}}$ is 166 000 ppm as the R-410A cardiac sensitization indicator.

$$c_{\text{blend}}\ \text{R-410A} = \frac{1}{\dfrac{0{,}698}{200\,000} + \dfrac{0{,}302}{567\,000}} \tag{D.4}$$

where

$c_{\text{R-32}}$ is the anaesthetic effect indicator NOAEL for R-32 or 250 000 ppm × 0,8 = 200 000 ppm;

$c_{\text{R-125}}$ is the anaesthetic effect indicator NOAEL for R-125 or 709 000 ppm × 0,8 = 567 000 ppm;

$c_{\text{R-410A}}$ is 249 000 ppm as the R-410A anaesthetic indicator.

NOTE EC_{50} was not used because there was no value for R-32 or R-125, and LOAEL was not used because the values for R-32 and R-125 affected over half (10/10 and > 5/10) the animals. Had legitimate EC_{50}, LOAEL or NOAEL values been available, it would have been possible to use a EC_{50} for one blend component, a LOAEL for a second, and a NOAEL for a third, etc.

There are no pertinent escape-impairing or permanent injury effect indicators d) known for R-410A. The lowest of acute TCFs a) to c) for the blend is set on the cardiac sensitization effect b), 166 000 ppm. Rounding to two significant figures gives 170 000 ppm as the ATEL of R-410A.

D.5 RCL for R-410A

The RCL shall be the lowest of the quantities calculated in accordance with ATEL (see 8.1.1.1), ODL (see 8.1.2) or FCL (see 8.1.3). Since the R-410A blend is non-flammable and the ATEL is 170,000 ppm, which is greater than the ODL of 140,000 ppm, the RCL is 140,000 ppm.

Annex E
(informative)

Data used to determine safety classification and RCL values and data for unclassified refrigerants

For data used to determine safety classification and RCL values, see Tables E.1 to E.3.

For data for unclassified refrigerants, see Tables E.4 to E.6.

Table E.1 — ATEL, ODL, FCL and RCL values single-compound refrigerants[a] (ppm volume fraction)

Refrigerant[b]	Chemical name	LC_{50}[c]	Cardiac sensitization		Anaesthesia			Other[i]	ATEL	ODL	FCL	RCL	ATEL source	RCL source
			LOAEL[e]	NOAEL[e]	EC_{50}[f]	LOAEL[g]	NOAEL[h]							
R-11	trichlorofluoro methane	26 200	5 000	1 100	35 000	ND	12 500	ND	1 100	140 000	NA	1 100	100 % cardiac NOAEL	ATEL
R-12	dichlorodifluoro methane	> 800 000	50 000	40 000	250 000	ND	200 000	22 700	18 000	140 000	NA	18 000	80 % Other	ATEL
R-14	tetrafluromethane	> 390 000	ND	200 000	ND	ND	226 000	ND	110 000	140 000	NA	110 000	28,8 % LC_{50}	ATEL
R-22	chlorodifluoromethane	220 000	ND	59 300[k]	140 000	50 000	ND	ND	59 000	140 000	NA	59 000	100 % cardiac NOAEL	ATEL
R-23	trifluoromethane	> 663 000	ND	800 000	ND	ND	51 000	ND	51 000	140 000	NA	51 000	80 % anaesthesia NOAEL	ATEL
R-32	difluoromethane (methylene fluroride)	> 760 000	250 000	200 000	ND	ND	250 000	ND	220 000	140 000	29 000	29 000	100 % Cardiac NOAEL	20 % LFL
R-113	1,1,2-trichloro-1,2,2-trifluoroethane	52 500	4 850	2 600	28 000	ND	25 000	ND	2 600	140 000	NA	2 600	100 % cardiac NOAEL	ATEL
R-114	1,2-dichloro-1,1,2,2-tetrafluoroethane	255 000[j]	25 000	ND	250 000	ND	100 000	ND	20 000	140 000	NA	20 000	80 % cardiac LOAEL	ATEL
R-115	chloropenta fluoroethane	> 800 000	150 000	ND	ND	ND	800 000	ND	120 000	140 000	NA	120 000	80 % cardiac LOAEL	ATEL
R-116	hexafluoroethane	> 800 000	ND	200 000	ND	ND	121 000	ND	120 000	140 000	NA	120 000	80 % anaesthesia NOAEL	ATEL
R-123	2,2-dichloro-1,1,1-trifluoroethane	32 000	ND	10 300	27 000	ND	2 500	ND	9 100	140 000	NA	9 100	28,8 % LC_{50}	ATEL
R-124	2-chloro-1,1,1,2-tetrafluoroethane	263 000	25 000	10 100	150 000	ND	48 000	ND	10 000	140 000	NA	10 000	100 % cardiac NOAEL	ATEL
R-125	pentafluoro ethane	> 769 000	100 000	75 000	ND	ND	709 000	ND	75 000	140 000	NA	75 000	100 % cardiac NOAEL	ATEL
R-134a	1,1,1,2-tetrafluoro ethane	> 359 000[l]	75 200	49 800	270 000	ND	81 000	ND	50 000	140 000	NA	50 000	100 % cardiac NOAEL	ATEL
R-141b	1,1-dichloro-1-fluoroethane	61 600	5 200	2 600	25 000	29 000	20 000	ND	2 600	140 000	15 000	2 600	100 % cardiac NOAEL	ATEL
R-142b	1-chloro-1,1-difluoroethane	106 000[d]	50 000	25 000	250 000	ND	591 000	ND	25 000	140 000	16 000	16 000	100 % cardiac NOAEL	20 % LFL
R-143a	1,1,1-trifluoro ethane	> 591 000	300 000	250 000	500 000	ND	24 800	ND	170 000	140 000	16 000	16 000	28,3 % LC_{50}	20 % LFL
R-152a	1,1-difluoro ethane	400 000[d]	150 000	50 000	ND	ND	100 000	500 000	50 000	140 000	9 600	9 600	100 % cardiac NOAEL	20 % LFL
R-170	ethane	> 24 800	100 000	ND	ND	ND	ND	ND	7 000	140 000	6 200	6 200	28,3 % LC_{50}	ATEL

Table E.1 *(continued)*

Refri-gerant[b]	Chemical name	LC$_{50}$[c]	Cardiac sensitization		Anaesthesia			Other[i]	ATEL	ODL	FCL	RCL	ATEL source	RCL source
			LOAEL[e]	NOAEL[e]	EC$_{50}$[f]	LOAEL[g]	NOAEL[h]							
R-E170	dimethyl ether	164 000	200 000	100 000	ND	84 000	ND	ND	42 000	140 000	6 800	6 800	50 % anaesthesia LOAEL	20 % LFL
R-218	octafluoro propane	> 400 000[d, m]	400 000	300 000	ND	ND	113 000	ND	110 000	140 000	NA	110 000	80 % anaesthesia NOAEL	ATEL
R-227ea	1,1,1,2,3,3,3-heptafluoro propane	> 788 696	105 000	90 000	ND	ND	105 000	ND	90 000	140 000	NA	90 000	80 % anesthetic NOAEL	ATEL
R-236fa	1,1,1,3,3,3-hexafluoro propane	> 457 000	150 000	100 000	110 000	ND	20 000	ND	55 000	140 000	NA	55 000	80 % anaesthesia EC$_{50}$	ATEL
R-245fa	1,1,1,3,3-pentafluoro propane	> 203 000	44 000	34 100	ND	ND	50 600	ND	34 000	140 000	NA	34 000	100 % cardiac NOAEL	ATEL
R-290	propane	> 200 000[n]	100 000	50 000	280 000	ND	ND	ND	50 000	140 000	4 200	4 200	100 % cardiac NOAEL	20 % LFL
R-C318	octafluoro cyclobutane	> 800 000	100 000	ND	> 800 000	ND	800 000	ND	80 000	140 000	NA	80 000	80 % Cardiac LOAEL	ATEL
R-600	butane	272 000	ND	ND	ND	ND	130 000	10 000	1 000	140 000	4 000	1 000	See 8.1.1.3	ATEL
R-600a	isobutane	143 000[o]	50 000	25 000	200 000	10 000	ND	ND	25 000	140 000	3 200	3 600	100 % cardiac NOAEL	20 % LFL
R-601	pentane	434 000	ND	ND	ND	16 000	32 000	ND	1 000	140 000	2 400	1 000	See 8.1.1.3	ATEL
R-601a	isopentane	434 000	ND	ND	ND	120 000	ND	ND	1 000	140 000	2 600	1 000	See 8.1.1.3	ATEL
R-717	ammonia	3 300[q]	ND	[p]	ND	[p]	38 900	400	320	140 000	33 000	320	Other	ATEL
R-744	carbon dioxide	[s]	ND	[p]	ND	[p]	ND	50 000[r]	40 000	140 000	NA	40 000	NIOSH IDLH	ATEL
R-1234yf	2,3,3,3-tetrafluoro -1-propene	> 406 000	ND	> 120 000	ND	201 000	ND	ND	100 000	140 000	12 000	12 000	50 % anaesthesia LOAEL	20 % LFL
R-1234ze(E)	trans-1,3,3,3-tetra-fluoro-1-propene	> 207 000	ND	> 120 000	ND	ND	> 207 000	ND	59 000	140 000	13 000	13 000	28,3 % LC$_{50}$	20 % LFL
R-1270	propene (propylene)	> 490 000[t]	ND	ND	ND	ND	10 000	7 200	1 000	140 000	5 400	1 000	See 8.1.1.3	ATEL

Table E.1 *(continued)*

Refri-gerant[b]	Chemical name	LC_{50}[c]	Cardiac sensitization		Anaesthesia			Other[i]	ATEL	ODL	FCL	RCL	ATEL source	RCL source
			LOAEL[e]	NOAEL[e]	EC_{50}[f]	LOAEL[g]	NOAEL[h]							

ND: Not determined or not adequately defined according to criteria of this International Standard.

NA: Not applicable.

[a] Reference [33].

[b] From ANSI/ASHRAE Standard 34-1997, including subsequent editions and addenda.

[c] 4-h LC_{50} rat used for mortality indicator.

[d] 4-h ALC rat used for mortality indicator; LC_{50} not determined.

[e] Dog with epinephrine injection.

[f] 10-min EC_{50} mouse or rat.

[g] Lowest anaesthetic/CNS LOAEL rat during ALC, LC_{50}, or other acute toxicity study.

[h] Highest anaesthetic/CNS NOAEL rat in any toxicity study not exceeding an acute LOAEL.

[i] Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures.

[j] R-114 30-min LC_{50} rat - 720 000 ppm by volume, 2-hr LC_{50} rat > 600 000 ppm by volume.

[k] See Reference [ ].

[l] R-134a LC_{50} substituted for ALC; >50 % of animals died at ALC of 566 700 ppm by volume.

[m] R-218 1-h ALC rat > 800 000 ppm by volume.

[n] R-290 15-min LC_{50} rat > 800 000 ppm by volume.

[o] R-600a 15-min LC_{50} rat = 570 000 ppm by volume; Anaesthetic/CNS value is a 17-min EC_{50} mouse

[p] No data, but believed to exceed LC_{50} and ALC.

[q] Published LC_{50} values - 6 586–19 671 ppm by volume for 1 h and 2 000–4 067 for 4 h; conversion of the lowest 1-h LC_{50} rat to 4-h yields 3 300, approximately the midpoint of the 4-h values.

[r] See NIOSH IDLH documentation for Other effect.

[s] R-744 treated as simple asphyxiant; 5-min LCLo human = 90 000 ppm by volume.

[t] R-1270 6-h ALC > 400 000 ppm by volume; cardiac sensitization in 2 of 2 dogs at 100 000 ppm; respiratory rate decrease in half of tested animals at 7 200 ppm by volume.

Table E.2 — LFL, ETFL, S_u and HOC for flammable refrigerants

Refrigerant number	**Chemical formula**	**LFL** % v/v	**ETFL$_{60}$** % v/v	S_u cm/s	**HOC** MJ/kg	
R-30	CH_2Cl_2		14,1		5,7	
R-32	CH_2F_2	14,4		6,7	9,5	
R-40	CH_3Cl	10,7			12,8	
R-41	CH_3F	7,1		28	19,6	
R-50	CH_4	5,0		40	50,0	
R-141b	CH_3CCl_2F	7,6			8,0	
R-142b	CH_3CClF_2	8,0			8,9	
R-143a	CH_3CF_3	8,2		7,1	10,3	
R-152a	CH_3CHF_2	4,8		23	16,3	
R-170	CH_3CH_3	3,1		47	47,5	
R-E170	CH_3OCH_3	3,4		54	28,8	
R-290	$CH_3CH_2CH_3$	2,1		46	46,3	
R-600	$CH_3CH_2CH_2CH_3$	1,6		45	45,7	
R-600a	$CH(CH_3)_2CH_3$	1,8		41	45,6	
R-610	$CH_3CH_2OCH_2CH_3$	1,9		47	34,1	
R-611	$HCOOCH_3$	5,0			15,3	
R-630	CH_3NH_2	4,9		25	31,4	
R-631	$CH_3CH_2NH_2$	3,5		27	35,2	
R-702	H_2	4,0		317	120,0	
R-717	NH_3	16,7		7,2	18,6	
R-744A	N_2O	NF			1,9	
R-1132a	$CH_2 = CF_2$	4,7			15,7	
R-1150	$CH_2 = CH_2$	3,1		80	47,2	
R-1234yf	$CF_3CF = CH_2$	6,2		1,5	10,7	
R-1234ze(E)	$CF_3CH = CHF$	6,5		1,2	10,1	
R-1270	$CH_3CH = CH_2$	2,7			45,8	

Table E.3 — LFL, ETFL$_{60}$, S_U and HOC for flammable refrigerant blends

Refrigerant Number	LFL			ETFL$_{60}$			S_U			HOC			
	Nominal	WCF	WCFF	Nominal	WCF	WCFF	Nominal	WCF	WCFF	Nominal	WCF	WCFF	
R-406A			8,2							7,7	8,2	10,1	
R-411A						5,5				5,7	6,3	14,1	
R-411B						7				5,3	5,3	12,0	
R-412A						8,7				5,0	5,0	8,9	
R-413A						8,8				7,6	11,2	8,6	
R-415A			5,6										
R-415B		4,7											
R-418A			8,9										
R-419A			6,0										
R-429A		2,5											
R-430A		3,2											
R-431A		2,2											
R-432A		2,2											
R-433A		2,0											
R-433B		1,8											
R-433C		1,8											
R-435A		3,4											
R-436A		1,6											
R-436B		1,6											
R-439A		10,4								9,5			
R-440A		4,6 (100C)								18,5			
R-441A		1,6								46,0			
R-511A		2,1								45,5			
R-512A			4,5							16,0			

Table E.4 — Refrigerant designations of unclassified single-compound refrigerants[c]

Refrigerant number	Composition designating prefix	Chemical name[b]	Chemical formula	Relative molar mass[a] g/mol	Normal boiling point[a] °C	LFL (ppm by volume)	ATEL (ppm by volume)	RCL (ppm by volume)
		Methane series						
R-12B1	BCFC	bromochlorodifluoromethane	$CBrClF_2$	165,4	-4			
R-13	CFC	chlorotrifluoromethane	$CClF_3$	104,5	-81			
R-13B1	BFC	bromotrifluoromethane	$CBrF_3$	148,9	-58			
R-21	HCFC	dichlorofluoromethane	$CHCl_2F$	102,9	9			
R-30	HCC	dichloromethane (methylene chloride)	CH_2Cl_2	84,9	40			
R-31	HCFC	chlorofluoromethane	CH_2ClF	68,5	-9			
R-40	HCC	chloromethane (methyl chloride)	CH_3Cl	50,5	-24	107 000		
R-41	HFC	fluoromethane (methyl fluoride)	CH_3F	34,0	-78	71 000		
R-405A	🟥	±2,0/±1,0/±1,0/±2,0 [b]	-32,9/-24,5			57 000	57 000	

Table E.4 *(continued)*

Refriger-ant number	Com-posi-tion desig-nating prefix	Chemical name[b]	Chemical formula	Relative molar mass[a] g/mol	Normal boiling point[a] °C	LFL (ppm by volume)	ATEL (ppm by volume)	RCL (ppm by vol-ume)
R-50	HC	methane	CH_4	16,0	-161	50 000		
		Ethane series						
R-141b	HCFC	1,1-dichloro-1-fluoroethane	CH_3CCl_2F	117,0	32	76 000	2 600	2 600
		Oxygen compounds						
R-610		ethoxyethane (diethyl ether)	$CH_3CH_2OCH_2CH_3$	74,1	35	19 000		
R-611		methyl formate	$HCOOCH_3$	60,0	32	50 000		
		Nitrogen compounds						
R-630		methanamine (methyl amine)	CH_3NH_2	31,1	-7	49 000		
R-631		ethanamine (ethyl amine)	$CH_3CH_2NH_2$	45,1	17	35 000		
		Sulfur compounds						
R-620		(Reserved for future assignment)						
		Inorganic compounds						
R-702		hydrogen	H_2	2,0	-253	40 000		
R-704		helium	He	4,0	-269			
R-718		water	H_2O	18,0	100			
R-720		neon	Ne	20,2	-246			
R-728		nitrogen	N_2	28,1	-196			
R-732		oxygen	O_2	32,0	-183			
R-740		argon	Ar	39,9	-186			
R-744A		nitrous oxide	N_2O	44,0	-90			
R-764		sulfur dioxide	SO_2	64,1	-10			
		Unsaturated organic compounds						
R-1132a	HFO	1,1-difluoroethene (vinylidene fluoride)	$CH_2=CF_2$	64,0	-82	47 000		
R-1150	HC	ethene (ethylene)	$CH_2=CH_2$	28,1	-104	31 000		

[a] The relative molar mass and normal boiling point are not part of this International Standard. The normal boiling point is the temperature at which a liquid substance boils at standard atmospheric pressure (101,3 kPa).

[b] The preferred chemical name is followed by the popular name in parentheses. The preferred chemical name and formula are in accordance with Reference [3] or Reference [4].

[c] Unclassified refrigerants indicate either insufficient data to classify or no formal request for classification.

Table E.5 — Refrigerant designations of unclassified R400 blends[c]

Refrigerant number	**Nominal composition**[a] mass fraction %	**Composition tolerance** %	**Bubble point/ dew point at 101,3 kPa** °C[b]	**LFL** (ppm by volume)	**ATEL** (ppm by volume)	**RCL** (ppm by volume)
R-400	R-12/114 (shall be specified)					
	R-12/114 (50,0/50,0)					28 000
	R-12/114 (60,0/40,0)					30 000

[a] Blend components are listed in order of increasing normal boiling point.

[b] The “bubble point” and the “dew point” temperatures are not part of this International Standard; they are provided for information only. The “bubble point” is defined as the liquid saturation temperature of a refrigerant; the temperature at which a liquid refrigerant first begins to boil. The “dew point” is defined as the vapour saturation temperature of a refrigerant; the temperature at which the last drop of liquid refrigerant boils. The dew point of a zeotropic refrigerant blend, at constant pressure, is higher than the bubble point.

[c] Unclassified refrigerants indicate either insufficient data to classify or no formal request for classification.

Table E.6 — Refrigerant designations of unclassified R500 blends[f]

Refrigerant number	**Nominal composition**[e] mass fraction %	**Composition tolerance** %	**Azeotropic temperature** °C[d]	**Bubble point/ dew point at 101,3 kPa** °C[ab]	**LFL** (ppm by volume)	**ATEL** (ppm by volume)	**RCL** (ppm by volume)
R-503	R-23/13 (40,1/59,9)		-88	-87,5/-87,5			
R-504	R-32/115 (48,2/51,8)		17	-57,1/-56,2		220 000	140 000
R-505	R-12/31 (78,0/22,0)[c]	±2,0/±2,0	115	-30,0/ND			
R-506	R-31/114 (55,1/44,9)	±2,0/±2,0	18	-12,0/ND			

[a] The “bubble point” and the “dew point” temperatures are not part of this International Standard; they are provided for information only. The “bubble point” is defined as the liquid saturation temperature of a refrigerant; the temperature at which a liquid refrigerant first begins to boil. The “dew point” is defined as the vapour saturation temperature of a refrigerant; the temperature at which the last drop of liquid refrigerant boils. The dew point of a zeotropic refrigerant blend, at constant pressure, is higher than the bubble point. ND indicates not determined.

[b] Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they are formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.

[c] The exact composition of this azeotrope is in question, and additional experimental studies are needed.

[d] Under vapour-liquid equilibrium conditions.

[e] Blend components are listed in order of increasing normal boiling point.

[f] Unclassified refrigerants indicate either insufficient data to classify or no formal request for classification.

Annex F
(normative)

Application instructions

F.1 General

This annex identifies requirements to apply for designations, safety classifications, and RCL values for refrigerants, including blends, in addenda or revisions to this International Standard.

F.2 Eligibility

F.2.1 Applicants

Any interested party may request designations and safety classifications for refrigerants. Applicants may be individuals, organizations, businesses, or government agencies. A primary contact shall be identified for groups of individuals, organizations, businesses, or agencies.

F.2.2 Fee

There is no application fee, but applicants should contact the ISO 817 Maintenance Agency secretariat to determine whether or not there are any charges for shipping and/or copying the application.

F.2.3 Timing

Applications may be submitted at any time. Committee consideration will be deferred if received by committee members less than 30 calendar days before a scheduled meeting. Applicants may communicate with the secretariat (see F.10.4) to determine when the next meeting is scheduled and the additional lead-time required. Consideration also may be deferred, by vote of the majority of voting members present, if inadequate opportunity was afforded for review based on the number or complexity of applications received for a specific meeting.

F.2.4 Precedence

Applications shall be addressed in the order received. Early submission is beneficial in the event that too many applications are received for consideration at a specific meeting.

F.2.5 Amendments

An application could be accepted, suspended or rejected by the MA. A suspended application may be amended by the applicant. Pending applications may be amended to revise or add information whether initiated by the applicant or in response to a committee request for further information. Amended applications shall be re-sequenced to the date of receipt of the last amendment to determine the order of consideration. Amendments shall be separated into the parts indicated in F.3, beginning the information for each part on a new page to facilitate insertion in the original or previously amended application. Amendments shall repeat the data certification specified in F.5.2. Rejected applications may not be amended, but they may be resubmitted in their entirety as new applications based on new information that might become available

An application will be rejected if it does not meet the requirements of this International Standard and the applicant has not shown reasonable progress towards remedying the deficiency within 18 months or after 3 meetings of the MA. (See Guidelines for the Maintenance of ISO 817).

F.2.6 Blends

F.2.6.1 Components

The components of refrigerant blends shall be individually classified before safety classifications are assigned to blends containing them. Applications for designation and classification of blends, therefore, shall be accompanied or preceded by applications for all components not yet classified in this International Standard.

F.2.6.2 Single application

A designation, formulation tolerances, and safety classifications (both as formulated and for the worst case of fractionation) shall be requested in a single application for blends. None of these shall be assigned separately. Revisions of these items may be requested separately.

F.2.7 Confidentiality

Confidential information shall not be included in applications. All information contained in applications and amendments thereto shall be deemed to be public information, even if marked as confidential or proprietary. Restricted handling of data would unduly impede committee deliberations and assignment of designations and classifications through a consensus review process.

F.3 Organization and content

Separate applications shall be submitted for each refrigerant. Applications shall be organized into the following parts as further identified in F.4 to F.9:

a) cover;

b) administrative information;

c) designation information;

d) toxicity information;

e) flammability information;

f) other safety information (if applicable);

g) appendices (if applicable).

F.4 Cover

The cover shall identify the applicant and primary contact, the refrigerant in accordance with F.6.1, and requested action. Requested actions may include assignment or revision of a designation, safety classification, RCL value, or (for blends) formulation tolerance. Commercial and trade names for refrigerants shall not be used on the cover.

F.5 Administrative information

F.5.1 Applicant identification

The applicant, primary contact, and other persons authorized to represent the applicant shall be identified. Names, titles, addresses, and phone numbers shall be provided for the primary contact and other representatives. Fax numbers and electronic-mail addresses also may be provided to facilitate communications. The applicant's interest in the subject refrigerant shall be stated.

F.5.2 Data certification

An application shall include the following statements signed by the individual(s) or, for organizations and businesses, both a corporate officer and the primary contact:

I/We certify that the information provided in this application (including its appendices) is true and accurate to the best of my/our knowledge and that no information that would affect classification of toxicity or flammability safety is being withheld. I/We further certify that I/we have reviewed ISO 817 (including all published addenda thereto) and that the information provided in this application is consistent with the requirements of that standard. We believe that the data submitted supports a safety classification of ____ (*select one: A1, A2L, A2, A3, B1, B2L, B2, B3*).

F.5.3 Designation and classification certification

Applications shall include the following statement signed by the individual(s) or, for organizations and businesses, both a corporate officer and the primary contact:

I/We understand that designations and safety classifications recommended for [public review approval or publication] are not assigned and may be revised or disapproved until actually published in an addendum or revision to ISO 817.

F.6 Designation information

Applications for refrigerant designations shall contain the information identified in F.6.1 to F.6.2.

F.6.1 Refrigerant identification

F.6.1.1 Single-compound refrigerants shall be identified in accordance with Clause 3 with the exception of 4.4, which applies to blends.

F.6.1.2 Blends shall be identified by listing the individual components in order of increasing normal boiling point followed by the composition as a mass fraction (%). For example, a 10,0/90,0 mass fraction (%) mixture of Refrigerants 12 and 22 shall be indicated as R-22/12 (90,0/10,0). Applicants shall indicate whether the blend is azeotropic or zeotropic (including near azeotropic) as defined in Clause 2.

F.6.2 Refrigerant data

F.6.2.1 Individual compounds

The following information shall be provided for single-compound refrigerants or for each component of blends:

a) Chemical name.

b) Chemical formula.

c) Chemical Abstract Service registry number.

d) Relative molar mass.

e) Freezing or triple point.

f) Normal boiling point at 101,3 kPa.

g) Saturation vapour pressure at 20 °C and 60 °C.

h) Temperature at the critical point.

i) Pressure at the critical point.

j) Specific volume at the critical point.

k) Uses and typical application temperatures (i.e. evaporating and condensing ranges).

l) Hazard signals in accordance with NFPA 704 or the equivalent International Standard.

F.6.2.2 Azeotropic blends

The following additional information shall be provided for azeotropes:

a) Azeotropic temperature.

b) Formulation at the azeotropic temperature.

c) Relative molar mass as formulated.

d) Relative molar mass of the saturated vapour at 60 °C.

e) Normal boiling point temperature (bubble-point temperature) at 101,3 kPa as formulated.

f) Normal dew-point temperature at 101,3 kPa as formulated.

g) Maximum temperature glide at the normal boiling point and at 20 °C.

h) Vapour composition for the as formulated saturated liquid composition at the normal boiling point and at 20 °C.

i) Saturation vapour pressure at 20 °C and 60 °C as formulated.

j) Evidence of azeotropy, including a detailed description of testing and a vapour-liquid equilibrium diagram (optional supporting information may be provided as an appendix).

k) Temperature at the critical point.

l) Pressure at the critical point.

m) Specific volume at the critical point.

n) Uses and typical application temperatures (i.e. evaporating and condensing ranges).

o) Proposed composition tolerances for classification.

p) Worst case formulation (WCF) of the blend.

q) Worst case fractionated formulation (WCFF) of the blend.

r) Hazard signals in accordance with NFPA 704 or the equivalent International Standard.

F.6.2.3 Zeotropic blends

The following additional information shall be provided for zeotropes (including near azeotropes):

a) Formulation.

b) Relative molar mass as formulated.

c) Relative molar mass of the vapour at 60 °C.

d) Bubble-point temperature at 101,3 kPa.

e) Dew-point temperature at 101,3 kPa.

f) Maximum temperature glide at the normal boiling point and at 20 °C.

g) Vapour composition for the as formulated saturated liquid composition at the normal boiling point and at 20 °C.

h) Dew-point vapour pressure at 20 °C and 60 °C.

i) Temperature at the critical point.

j) Pressure at the critical point.

k) Specific volume at the critical point.

l) Uses and typical application temperatures (i.e. evaporating and condensing ranges).

m) Proposed composition tolerances for classification.

n) Worst case formulation (WCF) of the blend.

o) Worst case fractionated formulation (WCFF) of the blend.

p) Hazard signals in accordance with NFPA 704 or the equivalent International Standard.

F.6.2.4 Refrigerants with low critical temperatures

If the critical temperature is less than a temperature at which data are required in F.6.2.1, F.6.2.2 and F.6.2.3, substitute as follows:

a) For data requirements at 20 °C, provide the required data at the normal boiling point or 0 °C, whichever is higher. For pressure data, also provide the pressure at 20 °C and the critical density.

b) For data requirements at 60 °C, provide the required data at a temperature calculated as the normal boiling point plus 80 % of the difference between the critical temperature and the normal boiling point. For pressure data, also provide the pressure at 60 °C and the critical density.

c) Indicate the applicable temperature, or temperature and critical density, at which the substitute data are provided.

F.6.2.5 Critical point for blends

For refrigerant blends, the critical temperature and pressure shall be calculated as the weighted average by mole fractions of the critical temperatures and pressures, respectively, of the blend components in the as-formulated composition.

F.7 Toxicity information

Applications for single-compound refrigerants shall include the data identified in F.7.1, F.7.2 and F.7.3. Applications for refrigerant blends shall include the data identified in F.7.3. The sources for these data shall be identified, and the applicant shall provide copies if requested by the MA. See F.2.6 regarding blend components.

F.7.1 Acute toxicity

Applications shall include the following short-term toxicity data, with identified sources, for single-compound refrigerants or for each component of blends:

a) ACGIH TLV-C if assigned,

b) ACGIH TLV-STEL if assigned,

c) NIOSH IDLH if assigned,

d) LC_{50} for 4 h for rats,

e) LD_{50} if available,

f) cardiac sensitization response level. (EC_{50} or LOAEL or NOAEL),

g) anaesthetic effect (EC_{50} or LOAEL or NOAEL),

h) information concerning other effects, which could cause escape-impairing symptom.

F.7.2 Chronic toxicity

For single-compound refrigerants or for each component of blends, applications shall include with identified sources:

a) repeat exposure toxicity data, if available,

b) ACGIH TLV-TWA or TLV-C if assigned,

c) TERA WEEL if assigned,

d) Recommended Permissible Exposure Limit value, determined on a basis consistent with the OSHA PEL (US) or the MAK (Germany), with an explanation of how it was determined.

F.7.3 Material safety data sheets (MSDSs)

Applications for single-compound refrigerants shall include an MSDS, or information consistent therewith, as an appendix. Applications for blends shall include MSDSs for the blend as formulated and for each component of the blend as appendices.

F.8 Flammability information

Applications for single-compound refrigerants and refrigerant blends shall include tabulated flammability test data and information identified in B.1.8. Applications for refrigerant blends shall also include tabulated fractionated data and information identified in B.2.5. See F.2.6 regarding blend components. If the refrigerant is flammable the application shall include the lower flammable limit. If A2L or B2L classification is requested, the maximum burning velocity, a description of the test method employed, the test results for the standard used to validate the test method and equipment, all test results determined for the refrigerant under consideration, and any other supporting evidence shall be included.

F.9 Auto-ignition temperature

Auto-ignition temperature data shall be included in the application. Measuring method shall be according to a published and recognized method such as UL 2182-2006.

F.10 Submission

F.10.1 Language

Applications shall be submitted in English.

F.10.2 Units

Applications shall be submitted in SI (metric) units.

F.10.3 Form

Required information and evidence shall be submitted in both printed format (by a word-processing application) and electronic format [portable document format (PDF)].

F.10.4 Recipient

Submit applications to the following address:

Secretariat, ISO TC 86/SC8

ASHRAE

1791 Tullie Circle NE

Atlanta, GA 30329-2305 USA

F.10.5 Elaborate applications

Elaborate proposals containing brochures on the applicant, performance data, and other material not needed for maintenance agency deliberations are discouraged.

Bibliography

[1] ISO 5149, *Mechanical refrigerating systems used for cooling and heating — Safety requirements*

[2] ISO 10298, *Determination of toxicity of a gas or gas mixture*

[3] International Union of Pure and Applied Chemistry (IUPAC) Blue Book and Guide. Nomenclature of Organic Chemistry, "Blue Book", IUPAC, Pergamon Press, 1979. Edited by J. Rigaudy and S.P., Lkesney

[4] Panico R., Powell W.H., Richer J.C. eds. *A Guide to IUPAC Nomenclature of Organic Compounds. Blackwell Scientific Publications*. References, 1993

[5] 1990-1991 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, USA, 1990

[6] OECD Principles of Good Laboratory Practice. Annex 2 of Decision C(81)30(Final), Organization for Economic Co-operation and Development (OECD), Paris, France, 13 May 1981

[7] Good Laboratory Practice for Nonclinical Laboratory Studies. Food and Drug Administration (FDA), 21 CFR Chapter 1 Part 58, Subparts A-K, Government Printing Office, Washington, DC, USA, 1996

[8] Good Laboratory Practice Standards. *Environmental Protection Agency, 40 CFR Part 792, Subparts A-J*. Government Printing Office, Washington, 1996

[9] GLP for Industrial Chemicals. Kikyoku [Basic Industries Bureau] Dispatch 85, Ministry of International Trade and Industry (MITI), and Kanpogyo [Planning and Coordination Bureau] Dispatch 39, Invrionmental Agency, Tokyo, Japan, 31 March 1984

[10] ten Berge W.F., Zwart A., Appelman L.M. Concentration-time mortality response relationship of irritant and systemically acting vapours and gases. *J. Hazard. Mater.* 1986, **13** (3) pp. 301–309

[11] Brock W.J., Rusch G.R., Trochimowicz H.J. Cardiac sensitization: methodology and interpretation in risk assessment. *Regul. Toxicol. Pharmacol.* 2003, **38** pp. 78–90

[12] *The Documentation of the Threshold Limit Values and Biological Exposure Indices*. 2003 p. 9, ACGIH, Cincinnati, Ohio

[13] *Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook*. American Industrial Hygiene Association, Fairfax, Virginia, 2005

[14] Takizawa K., Takahashi A., Tokuhashi K., Kondo S., Sekiya A. 2005, Burning velocity measurement of fluorinated compounds by the spherical-vessel method. *Combust. Flame*. 2005, **141** pp. 298–307

[15] Andrews G.E., & Bradely D. Determination of burning velocities: A critical review. *Combust. Flame*. 1972, **18** pp. 133–153

[16] Linett J.W. Fourth Symposium on Combustion, The Combustion Institute, p.20-34. 1953

[17] Coward H.F., & Payman W. Problems in flame propagation. *Chem. Rev.* 1937, **21** pp. 359–365

[18] Coward H.F. Hartwell F.J. Studies in the mechanism of flame movement. *J. Chem. Soc.* 1932, pp. 1996–2004 and pp. 2676–2684.

[19] Lewis B. von Elbe G. *Combustion, Flames and Explosions of Gases*.Second Ed., Academic Press, New York, 1961

[20] Jabbour T. Flammable Refrigerant Classification Based on the Burning Velocity, Thesis, Ecole des Mines de Paris, France, June 2004

[21] Guénoche H. Laffitte P. *Comptes Rendus de l'Académie des Sciences* **222** (12 Juin), pp. 1394–1396. P. 1946,

[22] Guénoche H., Manson N., Monnot G. *Comptes Rendus de l'Académie des Sciences* **226** (5 Jan.), pp. 69–71. 1948

[23] Guénoche H., Manson N., Monnot G. *Comptes Rendus de l'Académie des Sciences* **226** (12 Jan.), pp. 163–164. 1948

[24] Guénoche H. Non-steady flame propagation (Ed. G. H. Markstein), Chapter E. AGARD, Pergamon, 1964

[25] Babrauskas V. *Ignition Handbook*. Fire Science Publishers, 2003

[26] DIN 51649-1: 1986, *Determination of explosion limits of gas mixtures*

[27] Kondo S., Urano Y., Takahashi A., Tokuhashi K. Reinvestigation of flammability limits measurement of methane by the conventional vessel method with AC discharge ignition. *Combust. Sci. Technol.* 1999, **145** pp. 1–15

[28] Barnett H.C. Hibbard R.R., Basic Considerations in the Combustion of Hydrocabon Fuels with Air, National Advisory Committee for Aeronautics, Report 1300. 1957

[29] Durox D., & Ducruix S. Concerning the location of the schlieren limit in premixed flames. *Combust. Flame*. 2000, **120** pp. 595–598

[30] AHRI Standard 700, *Specifications for Fluorocarbon Refrigerants*

[31] NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, National Fire Protection Association, USA

[32] UL 2182-2006, *Refrigerants*

[33] CALM J.M M. "ARTI Refrigerant Database", Air-Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA

[34] American Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values for Chemical Substances and Physical Agents*

[35] IEC 60335-2-24, *Household and similar electrical appliances — Safety — Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice makers*

[36] IEC 60335-2-34, *Household and similar electrical appliances — Safety — Part 2-34: Particular requirements for motor-compressors*

[37] IEC 60335-2-40, *Household and similar electrical appliances — Safety — Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers*

[38] IEC 60335-2-89, *Household and similar electrical appliances — Safety — Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor*

ICS 71.100.45

Price based on 73 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™