International Standard

ISO 24499

Test method for burning velocity measurement of A2L flammable gases

Méthode d'essai pour mesurer la vitesse d'inflammabilité des gaz inflammables A2L

First edition
2026-09

Reference number
ISO 24499:2026(en)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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Foreword

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

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

This document was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 8, *Refrigerants and refrigeration lubricants*.

This first edition cancels and replaces ISO/PAS 24499:2024, which has been technically revised.

The main changes are as follows:

— the term "blend" was added to Clause 3;

— requirements were added to: 6.2 (to measure the concentration of gas mixture in the tube), 8.3 (to train personnel in potential system hazards and have HF safety kits available), 9.5 (to not neglect the effect on flame configuration) and 9.7 (on how to estimate the area of the tipped flame front);

— recommendations were added to: 6.3.7 (to compare the glass transmission profiles before selecting the type of glass) and 9.5 (to use a tube of cross-sectional area that is as large as possible).

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

Introduction

The safety classification and relative flammability properties of refrigerants are a critical part of ISO 817 [1]. The flammability limits of refrigerant gas in air, as described in ISO 817:2024 [2], Clause B.1, give a partial measure of the relative flammability. Another dimension of flammability is how fast a substance burns, releases energy and spreads a flame. It is possible to measure the rate at which a flame front moves through a cloud of refrigerant gas in air or its burning velocity (BV). This document describes one method that can be useful for BV measurement and thereby better quantify and compare relative flame fronts for some refrigerant classes. In this test, a flame is allowed to propagate upward (vertically) through a well-mixed, quiescent column of a refrigerant-air mixture enclosed in an open-ended glass tube. Optical systems are used to measure the upward velocity of the flame front.

The measurement of BV has been widely used in the past to compare highly energetic fluids, such as motor fuels and rocket propellants. The BV measurement of slow burning fluids, such as ammonia and fluorinated refrigerants, can be more difficult to measure due to the inherent instability of a slow flame. The low rate of energy evolution from a slow flame makes it susceptible to quenching from a variety of sources. For slow burning refrigerants, turbulence and convection currents can break the flame front and hence quench the flame. In addition, the test chamber surface can quench free radical flame intermediates as well as extract some of the heat necessary for flame propagation. Gas-phase thermal radiation is also important for flames with low BV. These effects are important to note as they tend to diminish and sometimes quench a weak flame.

The use of the vertical tube method for BV characterization of slow burning refrigerants was the subject of doctoral research which was used in ISO 817:2024 [2], Annex C and is the basis for this document[3]. In addition, ASHRAE research notes the use and limitations of the vertical tube technique[4][5]. While the basic framework of the method is relatively simple, some sophisticated imaging instrumentation and mathematics are necessary to extract an average local BV separate from the bulk burning speed as the flame progresses up the tube. Since 2004 other laboratories have used the basic principle of vertical tube method and have shown acceptable results for reproducing the measurement of R-32, at (6,7 ±0,7) cm/s. Lower burning velocities (i.e. <4 cm/s) make it more difficult to measure reproducibility, so variability can increase as flame instability increases. The lower BV limit of this method is between 3 cm/s and 4 cm/s, depending on the actual design and geometry of the apparatus being used. The uncertainty of the measurement of flames that burn more slowly than R-32 has not yet been determined in any multi-lab comparative testing. The appealing aspects of this test are the relative simplicity and low cost of its implementation. Therefore, the lower accuracy limit of this BV method is considered to be 4 cm/s; any data generated by this method which yields a lower value should be reported as <4 cm/s.

Test method for burning velocity measurement of A2L flammable gases

1 Scope

This document specifies a method of measuring the burning velocity (BV) of lower burning refrigerants (</= 10 cm/s) for use with other standards that utilize the BV for determining the safety classification of refrigerants (e.g. ISO 817 [1]) or that use the BV in establishing requirements on the use of slow burning refrigerants (e.g. ISO 817:2024 [2], 6.1.3.3).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1
blend
mixture composed of two or more *refrigerants* (3.11)

3.2
burning velocity
BV
S_u
maximum velocity at which a laminar *flame* (3.5) propagates in a normal direction relative to the unburned gas ahead of it

Note 1 to entry: This value is expressed in centimetres per second (cm/s).

3.3
combustion
exothermic reaction between an oxidant (e.g. air) and a combustible fuel

3.4
compound
substance composed of two or more atoms chemically bonded in definite proportions

3.5
flame
space where *combustion* (3.3) takes place, resulting in a temperature increase and light emission

3.6
flame propagation
combustion (3.3) causing a continuous *flame* (3.5) which moves upward and outward from the point of ignition without the influence of the ignition source

3.7
flame propagation velocity
S_s
velocity at which the continuous *flame* (3.5) moves upward and outward from the point of ignition without the point of ignition and without the influence of the ignition source

3.8
flame surface area
A_f
surface area of the *flame* (3.5) generated during the *combustion* (3.3) of the *flammable* (3.9) gas

3.9
flammable
property of a mixture in which a *flame* (3.5) is capable of self-propagating

3.10
quenching
effect of extinction of the *flame* (3.5) near a surface due to heat conduction losses, absorption of active chemical species and viscous effects of the surface

3.11
refrigerant
fluid used for heat transfer in a refrigerating system

Note 1 to entry: Refrigerants absorb 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.

3.12
stoichiometric concentration
C_{st}
concentration of a fuel in a fuel-air mixture that contains exactly the necessary quantity of air (approximately 21 % O_2 / 79 % N_2 by volume) needed for the complete oxidation of all the *compounds* (3.4)

4 General test method

4.1 General

The test method is based on:

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

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

c) determining the surface area of the flame.

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

This test method involves the use of hazardous substances and therefore requires, for 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 Clause 8.

4.2 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 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 BV, S_u, is calculated from the knowledge of the flame propagation velocity, S_s, in the tube and the ratio of the flame surface area to its base cross-sectional area. The volume of burned gas per second and per unit area, or the BV, 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 volume consumption of the mix 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 (1) is used to determine volume consumption per unit time.

$$S_u = S_s \times \frac{a_f}{A_f} \quad (1)$$

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 BV.

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 BV 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.