INTERNATIONAL STANDARD

ISO 3529-1

Second edition
2019-07

Vacuum technology — Vocabulary —

Part 1: General terms

Technique du vide — Vocabulaire —

Partie 1: Termes généraux

Reference number
ISO 3529-1:2019(E)

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Published in Switzerland

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Introduction

If difficulties arise in the use of the definitions in connection with measurement of some quantities, it is recommended that reference be made to the International Standards related to the measurement of those quantities for the practical interpretation of the terms.

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.

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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 112, *Vacuum technology*.

This second edition cancels and replaces the first edition (ISO 3529-1:1981), which has been technically revised. The main changes compared to the previous edition are as follows:

- standard conditions which are defined elsewhere were removed;
- ranges of vacuum were newly defined and reasons given;
- new term ultra clean vacuum was defined;
- knudsen number and rarefaction parameter were included;
- slip flow was defined;
- specific desorption, outgassing, and evaporation rate were newly defined;
- accommodation factor distinguished in energy and momentum accommodation factor.

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.

Vacuum technology — Vocabulary —

Part 1:
General terms

1 Scope

This document defines general terms used in vacuum technology. It gives theoretical definitions as precise as possible, bearing in mind the need for use of the concept in practice.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1 General terms

3.1.1
vacuum
commonly used term to describe the state of a rarefied gas or the environment corresponding to such a state, associated with a pressure or a molecular density below the prevailing atmospheric level

3.1.2
ranges of vacuum
various ranges of vacuum according to certain pressure intervals

Note 1 to entry: While there has been some variation in the selection of the limits of these intervals, the following list gives typical ranges for which the limits are to be considered as approximations.

Note 2 to entry: The prevailing atmospheric pressure on ground depends on weather conditions and altitude and ranges from 31 kPa (altitude of the Mount Everest, weather condition "low") up to 110 kPa (altitude Dead Sea, weather condition "high").

Pressure range	Definition	The reasoning for the definition of the ranges is as follows (typical circumstances):
Prevailing atmospheric pressure (31 kPa to 110 kPa) to 100 Pa	low (rough) vacuum	Pressure can be achieved by simple materials (e.g. regular steel) and positive displacement vacuum pumps; viscous flow regime for gases
<100 Pa to 0,1 Pa	medium (fine) vacuum	Pressure can be achieved by elaborate materials (e.g. stainless steel) and positive displacement vacuum pumps; transitional flow regime for gases

Pressure range	**Definition**	**The reasoning for the definition of the ranges is as follows (typical circumstances):**
<0,1 Pa to 1×10^{-6} Pa	high vacuum (HV)	Pressure can be achieved by elaborate materials (e.g. stainless steel), elastomer sealings and high vacuum pumps; molecular flow regime for gases
<$1 \text{x} 10^{-6}$ Pa to 1×10^{-9} Pa	ultra-high vacuum (UHV)	Pressure can be achieved by elaborate materials (e.g. low-carbon stainless steel), metal sealings, special surface preparations and cleaning, bake-out and high vacuum pumps; molecular flow regime for gases
below 1×10^{-9} Pa	extreme-high vacuum (XHV)	Pressure can be achieved by sophisticated materials (e.g. vacuum fired low-carbon stainless steel, aluminium, copper-beryllium, titanium), metal sealings, special surface preparations and cleaning, bake-out and additional getter pumps; molecular flow regime for gases

3.1.3
ultra clean vacuum

medium or high vacuum that requires special conditions for some gas species equivalent to UHV conditions

Note 1 to entry: The requirements for the particular gas species (impurity) depend on the application.

Note 2 to entry: Hydrocarbons, CO, CO_2 and H_2O are typical impurity gases.

Note 3 to entry: The particular requirements may also include specifications for low particle density.

3.1.4.1
pressure of a vacuum

p

<on a boundary surface> normal component of the force exerted by a gas on an area of a real surface divided by that area

Note 1 to entry: The orientation of the surface relative to the mass flow vector being specified if there is a net mass flow of gas);

3.1.4.2
pressure of a vacuum

p

<at a specified point in a bulk of gas> state of a gas according to the ideal gas law with corrections for real gases if necessary

Note 1 to entry: When the ideal gas law is applied, the pressure p in a small infinitesimal volume is given by the product of number density n of gas molecules in this volume, Boltzmann constant k and temperature T.

Note 2 to entry: For most practical applications in vacuum, the ideal gas law without corrections for real gases (volume and interaction of gas molecules) is sufficient.

3.1.5
partial pressure

pressure due to a specified component of a gaseous mixture

3.1.6
total pressure

term used to denote the sum of all the partial pressures of the constituents of a gas mixture in contexts where the shorter term "pressure" might not clearly distinguish between the individual partial pressure and their sum

3.2 Terms to define gases and vapours and their parameters

3.2.1
gas
matter in a state such that the molecules are virtually unrestricted by intermolecular forces so that the matter is free to occupy any available space

Note 1 to entry: In vacuum technology the word "gas" has been loosely applied to both the non-condensable gas and the vapour.

3.2.2
non-condensable gas
gas whose temperature is above the critical temperature of the substance considered, i.e. one which cannot be changed into the condensed phase by increase of pressure alone

3.2.3
vapour
gas whose temperature is below the critical temperature of the substance considered, i.e. one which can be changed into the condensed phase by increase of pressure alone

3.2.4
saturation vapour pressure
p_{L}
pressure exerted by a vapour which is in thermodynamic equilibrium with one of its condensed phases at the prevailing temperature

3.2.5
degree of saturation
ratio of the pressure exerted by a vapour to its saturation vapour pressure

3.2.6
saturated vapour
vapour which exerts a pressure equal to the saturation vapour pressure at a given temperature

Note 1 to entry: The vapour is always saturated when it is in thermodynamic equilibrium with one of the condensed phases of the substance considered.

3.2.7
unsaturated vapour
vapour which exerts a pressure less than the saturation vapour pressure of the substance considered for a given temperature

3.2.8
number density of molecules
n
<at a specified point in a gas and at a certain instant> number of molecules contained at time t in an adequately chosen volume surrounding that point, divided by that volume

Note 1 to entry: The word "time" is used for brevity. More exactly, an average is to be taken over a short time interval, centred about the time, of sufficient duration so that an adequate statistical average may be obtained.

3.2.9
unitary mass density
ρ_u
mass density of a gas divided by its pressure

3.2.10
bulk velocity

v

average velocity of molecules contained at time t in an adequately chosen volume surrounding that point

Note 1 to entry: The volume has to be chosen large enough that it contains a sufficient number of molecules so that a robust statistical result can be obtained and small enough that the obtained value does not significantly change in this volume.

3.2.11
temperature

T

quantity proportional to the average kinetic energy of molecules contained at time t in a small volume calculated in the reference frame related to the bulk velocity in the same volume

Note 1 to entry: See note to entry in 3.2.10

3.2.12
quantity of gas in pressure-volume units

pV

perfect gas statistically at rest, the product of the volume occupied, and its pressure

Note 1 to entry: One shall specify the temperature of the gas.

Note 2 to entry: This quantity so defined is equal to the quotient of the mass of the gas by its unitary mass density.

Note 3 to entry: It is two-thirds of the intrinsic (or potential) energy of the gas contained in the occupied volume.

3.3 Terms needed to characterize the movement of gas molecules and the flow of gases

3.3.1
mean free path of molecules

l, λ

average distance which a molecule travels between two successive collisions with other molecules of the gas

Note 1 to entry: The average should be taken over a sufficiently large number of molecules and over a sufficiently long time interval to provide a statistically significant value.

Note 2 to entry: In this concept of mean free path, it is assumed that the interaction of molecules cuts off at a certain distance of the molecules (hard sphere model or cut-off potentials). The mean free path can also be defined for other types of interaction (e.g. Lennard_Jones potential). In this case, the quantity is equal to the mean free path of a gas modelled by hard spheres having the same viscosity, temperature and density as the gas under observation.

3.3.2
Knudsen number

K, Kn

ratio of mean free path to a characteristic dimension of a duct or a vessel

Note 1 to entry: For a circular tube, the characteristic dimension of the duct is the diameter, for a duct of rectangular cross section, it is the smaller side of the rectangle.

3.3.3
rarefaction parameter

δ

ratio of a characteristic dimension of a duct or a vessel and the mean free path

Note 1 to entry: For a circular tube, the characteristic dimension of the duct is the diameter, for a duct of rectangular cross section, it is the smaller side of the rectangle.

Note 2 to entry: The rarefaction parameter is inversely proportional to the Knudsen number.

3.3.4
collision rate
ν
average number of collisions suffered, in a given interval of time, by a molecule (or other specified particle) in moving relative to the other molecules of a gas (or specified collection of particles) divided by that time

Note 1 to entry: The average should be taken over a sufficient large number of molecules and over a sufficiently long time interval to provide a statistically significant value.

3.3.5
diffusion of gas
movement of a gas in another medium due to a concentration gradient

Note 1 to entry: The medium may be another gas (in that case the diffusion is said to be "mutual") or a condensed medium.

3.3.6
diffusion coefficient
diffusivity
D
absolute value of the mass flow rate per unit area divided by the density gradient, where the area is normal to the gradient

3.3.7
viscous flow
passage of a gas through a duct under conditions such that the mean free path is very small in comparison with the smallest internal dimension of a transverse section of the duct, the flow being therefore dependent on the viscosity of the gas

Note 1 to entry: The flow may be laminar or turbulent.

3.3.8
Poiseuille flow
particular case of flow through a long pipe inducted by pressure difference across it

Note 1 to entry: When the flow is laminar and the cross-section of pipe is circular, the flow is especially called as Hagen-Poiseuille flow.

3.3.9
molecular flow
passage of a gas through a duct under conditions such that the mean free path is very large in comparison with the largest internal dimension of a transverse section of the duct

3.3.10
intermediate flow
transitional flow
passage of a gas through a duct under conditions intermediate between viscous flow and molecular flow

3.3.11
slip flow
passage of a gas through a duct under conditions such that the mean free path is smaller but not much in comparison with a characteristic dimension of the duct, the flow being therefore subject to the velocity slip condition on the duct walls

Note 1 to entry: For the characteristic dimension of the duct, see Note 1 in 3.4.7.

Note 2 to entry: For conditions of slip flow, the bulk velocity is not assumed to be zero at the wall of the duct as it is assumed under viscous flow conditions.

Note 3 to entry: Conditions of slip flow are intermediate between transitional and viscous flow.

3.3.12

molecular effusion; effusive flow

passage of gas through an aperture under conditions such that the largest dimension of the opening is smaller than the mean free path

3.3.13

transpiration

flow of a gas through a porous solid, due to a difference of pressure

3.3.14

thermal transpiration

passage of gas between two connected volumes due to a difference in the temperatures of the vessels which results in a pressure gradient when gas transfer equilibrium is reached

3.3.15

molecule flow rate

molecular flux

q_N

difference between the number of molecules which, in a given interval of time, cross the area, S, in a given direction and the number of those that cross, S, in the opposite direction, divided by that time

3.3.16

molecule flow rate density; density of molecular flux

molecule flow rate divided by the area of the cross-section area

3.3.17

throughput

q_{pV}

quantity of gas (in pressure-volume units) passing through a cross-section in a given interval of time, divided by that time

Note 1 to entry: It is also the mass flow rate divided by the unitary mass density.

3.3.18

mass flow rate

q_m

mass of gas crossing the area, S, in a given interval of time, divided by that time

3.3.19

volume flow rate

q_V

volume of gas at a specified temperature and pressure crossing the area S in a given interval of time, divided by that time

3.3.20

molar flow rate

q_ν

number of moles of a given gas crossing the area, S, in a given interval of time, divided by that time

3.3.21

maxwellian velocity distribution

velocity distribution which corresponds to the velocity distribution function of Maxwell-Boltzmann

Note 1 to entry: It is the velocity distribution of gas molecules which are at equilibrium for a given temperature.

3.3.22

transmission probability

P_C

probability that a molecule which enters the inlet port of a duct at random passes the outlet port of the duct without having passed the inlet port in the opposite direction

3.3.23
molecule conductance
C_N, U_N
<of an orifice or between two specified cross-sections of a duct> molecule flow rate divided by the difference in the average number density of molecules at both sides of the orifice or at the two cross-sections of the duct

3.3.24
conductance
C, U
<of a duct, or part of a duct, or an orifice> throughput divided by the difference in mean pressures prevailing at two specified cross-sections or at both sides of the orifice, assuming isothermal conditions

3.3.25
intrinsic conductance
$C_{i,}$, U_i
conductance in the special case where the duct (or the orifice) connects two vessels under the condition that Maxwellian velocity distribution prevails in the vessels

Note 1 to entry: In the case of molecular flow, it is equal to the product of the conductance of the inlet port and the transmission probability.

3.3.26
resistance
w
reciprocal of the conductance

3.4 Terms to define surface und bulk effects in vacuum technology

3.4.1
sorption
taking up of a gas or vapour (the sorbate) by a solid or a liquid (the sorbent)

3.4.2
adsorption
sorption in which the gas or the vapour (the adsorbate) is retained at the surface of the solid or the liquid (the adsorbent)

3.4.3
physisorption
sorption due to the physical forces in which no definite chemical bonding occurs

3.4.4
chemisorption
sorption in which the formation of chemical bonds occurs

3.4.5
absorption
sorption in which the gas (the absorbate) diffuses into the bulk of the solid or liquid (the absorbent)

3.4.6
energy (thermal) accommodation coefficient
α
ratio of the mean energy actually transferred between impinging particles and a surface, to the mean energy which would have to be transferred for the impinging particles to return from the surface having reached complete thermal equilibrium with the surface

3.4.7
momentum accommodation coefficient

σ

ratio of the mean momentum actually transferred between impinging particles and a surface, to the mean momentum which would have to be transferred for the impinging particles to return from the surface having reached complete thermal equilibrium with the surface

3.4.8
impingement rate

φ

number of molecules impinging on a surface in a given interval of time, divided by that time and the area of the surface

3.4.9
condensation rate

number of molecules (or amount of substance, or mass of substance) which condense on a surface in a given interval of time, divided by that time and the area of the surface

3.4.10
sticking rate

number of molecules which are sorbed on a surface in a given interval of time, divided by that time and the area of the surface

3.4.11
sticking probability

P_S

ratio of the sticking rate to the impingement rate

3.4.12
residence time

τ

average time which molecules remain bounded to surface in a state of sorption

3.4.13
migration

motion of adsorbed molecules on a surface

3.4.14
desorption

liberation of gases or vapours sorbed by a material

Note 1 to entry: The liberation can be spontaneous and can be accelerated by physical processes.

3.4.15
degassing

deliberate desorption of gas from a material

3.4.16
outgassing

spontaneous desorption of gas from a material

3.4.17
specific evaporation rate

number of molecules (or amount of substance, or mass of substance) which evaporate from a surface in a given interval of time, divided by that time and the area of the surface