EXHIBIT 1018

DK 621.521 : 533.5 : 001.4 GERMAN STANDARD **May 1990**

Vacuum technology – Terms and Definitions – General terms DIN 28 400 Part 1

Replacement for Edition 07.79

In conjunction with International standard ISO 3529-1:1981 published by the International Organization for Standardization (ISO) – see notes.

Contents

		Page
1	Fundamental concepts, vacuum ranges and units……...	1
2	Terms and definitions from the kinetic theory of gases……..	2
3	Terms and definitions for gas flow…….	3
4	Terms and definitions from surface and solid state physics……...	5
List of keywords…….		7

1 Fundamental concepts, vacuum ranges and units

1.1 Vacuum

Vacuum refers to the state of a gas
when the pressure of the gas, and thus the number density of molecules, in a container is lower than outside, or
when the pressure of the gas is lower than 300 mbar, i.e. lower than the lowest atmospheric pressure on the Earth's surface.

Note: the correlation between pressure p and number density of molecules n is

$p = nkT$ (strictly speaking, this formula is only valid for ideal gases)

k = Boltzmann constant

T = thermodynamic temperature

1.2 Ideal vacuum

Ideal vacuum within vacuum technology is the state in a compartment in which the number density of molecules is zero (previously referred to as "absolute vacuum").

1.3 Ranges of vacuum

Ranges of vacuum are ranges of pressures or number densities of molecules into which the vacuum is subdivided according to convention. The rounded limits of these ranges are listed in Table 1 in pressures or equivalent number density of molecules. The stated number densities of molecules apply for a temperature of t = 20°C.

Table 1. **Ranges of vacuum**

Symbol	Unit	Rough (low) vacuum	Medium vacuum	High vacuum HV	Ultra-high vacuum UHV
p	Pa	$1\cdot10^{5}$ to $1\cdot10^{2}$	$1\cdot10^{2}$ to $1\cdot10^{-1}$	$1\cdot10^{-1}$ to $1\cdot10^{-5}$	$< 1\cdot10^{-5}$
p	mbar	$1\cdot10^{3}$ to 1	1 to $1\cdot10^{-3}$	$1\cdot10^{-3}$ to $1\cdot10^{-7}$	$< 1\cdot10^{-7}$
n	m^{-3}	$2.5\cdot10^{25}$ to $2.5\cdot10^{22}$	$2.5\cdot10^{22}$ to $2.5\cdot10^{19}$	$2.5\cdot10^{19}$ to $2.5\cdot10^{15}$	$< 2.5\cdot10^{15}$

Continued pages 2 to 9

Standards Committee for Vacuum Technology (NAV) in the DIN German Institute for Standardisation
Standards Committee for Units and Quantities (AEF) in DIN

URT EX1018
URT Umwelt und Recyclingtechnik v. Duesenfeld
IPR2024-00887

1.4 Pressure

a) Pressure of a gas on a boundary wall:
the pressure of a gas on a boundary wall is the area-related normal component of the force exerted by a gas on the wall (the orientation of the wall surface relative to the flow vector must be specified if there is a flow of gas).

b) Pressure at a specified point within the gas compartment:
Pressure at a specified point within the gas compartment is the quotient of the pulse transported in a time interval by a surface element of a plane through said point in both directions and the product of the surface area of this element and the time interval (the orientation of the plane relative to the flow vector must be specified if there is a flow of gas).

Note: "Pressure" *per se* relates here to the pressure in a stationary gas or to the static pressure in a gas flowing under stationary conditions.

1.5 Pressure units [1]

The legal pressure units are the pascal as the SI unit, symbol Pa,

$$1 \text{ Pascal} = 1 \text{ N/m}^2$$

$$1 \text{ Pa} = 1 \text{ N}\cdot\text{m}^{-2}$$

and the bar, symbol bar, as a special unit name for 10^5 Pa,

$$1 \text{ bar} = 1000 \text{ mbar} = 10^5 \text{ Pa} = 10^5 \text{ N}\cdot\text{m}^{-2}.$$

The usual unit in vacuum technology is the millibar. The numerical relationships between the legal units and the earlier usual units are summarised in a table in Supplementary Sheet 1 to DIN 28 400.

1.6 Partial pressure

The partial pressure is the pressure of a particular gas (see section 1.8) or vapour (see section 1.9) in a mixture of gases and/or vapours.

1.7 Total pressure

The total pressure is the sum of the partial pressures of the present gases or vapours. The word is used when the shorter term "pressure" in a given context might not clearly distinguish between the individual partial pressures and the sum thereof.

1.8 Gas (general)

Gas is matter in an aggregate state in which the average distances between the molecules are large compared with the dimensions thereof and the mutual arrangement of the individual molecules constantly changes. Gas is not limited with respect to shape or volume.

1.8.1 Standard conditions of a gas

The standard condition of a gas is the reference condition fixed by the standard temperature

$$T_n = 273.15 \text{ K or } t_n = 0°\text{C}$$

and the standard pressure

$$P_n = 101325 \text{ Pa} = 1.01325 \text{ bar}$$

(from DIN 1343/01.90)

1.8.2 Standard volume of a gas

The volume of a gas in the standard condition, i.e. at standard temperature and standard pressure, is referred to as standard volume V_n
(from: DIN 1343/01.90).

1.8.3 Molar volume of a gas

The molar volume V_m of a gas is the volume relative to the amount of substance.
For an ideal gas in the standard condition, V_m is:

$$V_m = RT_n/P_n = 2.2414\cdot10^{-2}\text{m}^3/\text{mol} = 22.414 \text{ l/mol}$$

1.9 Vapour

Vapour is matter in the gaseous state which is either in thermodynamic equilibrium with its liquid or solid phase (saturated vapour) or can be brought into thermal equilibrium (condensed) by compression at the prevailing temperature (unsaturated vapour).

Note: in vacuum technology, the word "gas" is used in the broadest sense for a non-condensable gas and also for vapor if a distinction is not required.

1.10 Saturation vapour pressure

The saturation vapour pressure is the pressure exerted by a vapour which is in thermodynamic equilibrium with one of its condensed phases at the prevailing temperature.

2 Terms and definitions from the kinetic theory of gases

Note: within this section, the term "molecules" refers to neutral molecules (atoms, molecules, molecular fragments, molecular aggregates) if these can be applied to the kinetic theory of gases.
Exception: in sections 2.1 and 2.1.1, the term "molecules" is used for neutral and charged molecules without consideration of their applicability to the kinetic theory of gases.

---

[1] See DIN 1301 Part 1

2.1 Number density of molecules

The number density of molecules is the volume-related number of molecules in an adequately chosen volume.

2.1.1 Concentration of molecules of given component *i* in a mixture of gas

The concentration of molecules of a given component *i* in a mixture of gas is the quotient of the number of molecules of this gas component contained in an adequately chosen volume, and the content of the volume.

2.2 Speed of molecules

The thermal speed of molecules is the non-directional proportion of the proper motion of the gas molecules. The different speeds thereof are distributed according to the Maxwell-Boltzmann distribution function.

Note: The following speeds of molecules depend on the molar molecular mass and the thermodynamic temperature. The conversion factors thereof are listed in Table 2.

2.2.1 Average speed of molecules $\bar{c}$

The average speed of molecules $\bar{c}$ is the average value of the speeds of the molecules.

2.2.2 Most probable speed $\hat{c}$

The most probable speed $\hat{c}$ is the value of the speed of molecules which corresponds to the maximum of the Maxwell-Boltzmann distribution function.

2.2.3 Root mean square speed of molecules $\sqrt{\overline{c^2}}$

The root mean square speed of molecules $\sqrt{\overline{c^2}}$ is the root of the average value of the squares of the speed of molecules.

Table 2. **Conversion factors for speeds of molecules**

	$\bar{c}$	$\hat{c}$	$\sqrt{\overline{c^2}}$
$\bar{c}$	1	$\frac{2}{\sqrt{\pi}} = 1.128$	$\sqrt{\frac{8}{3\pi}} = 0.921$
$\hat{c}$	$\sqrt{\frac{\pi}{2}} = 0.886$	1	$\sqrt{\frac{2}{3}} = 0.816$
$\sqrt{\overline{c^2}}$	$\sqrt{\frac{3\pi}{8}} = 1.085$	$\sqrt{\frac{3}{2}} = 1.224$	1

Example: $\bar{c} = 1.128 \cdot \hat{c} = 0.921 \cdot \sqrt{\overline{c^2}}$

2.3 Mean free path

The mean free path is the average value of the distances which a molecule travels between two successive collisions with other molecules.

2.4 Collision rate [2]

The collision rate is the quotient of the average number of collisions with other molecules suffered by a molecule when moving through a gas during a time interval, and the time interval.

2.4.1 Volume collision rate

The volume-related collision rate is the quotient of the average number of collisions occurring between molecules in a volume during a time interval, and the product of the time interval and the volume of the element.

2.4.2 Surface collision rate

The area-related collision rate is the quotient of the average number of molecules in a stationary gas which strike a flat surface during a time interval, and the product of the time interval and the surface area of the element.

2.5 Monolayer time

The monolayer time is the time in which a monolayer (see DIN 28 400 Part 6) forms on the real surface for the respectively provided number density of molecules.

Note: for estimations, the monolayer time can, in a simplified manner, be assumed to be the reciprocal value of the product of the area-related collision rate and the square of the largest diameter of the molecules located in the gas compartment.

3 Terms and definitions for gas flow

3.1 Quantity of gas (pressure-volume units) (pV value)

The quantity of gas (pV value) is the product of the pressure and volume of a particular amount of gas at the prevailing temperature.

Note: If the quantity of gas is to be a measurement of the amount of substance or the mass of the gas, then it must be an ideal gas, the temperature of which must be specified.

[2] Dependent on the number density of molecules

3.2 Dynamic gas flow

The dynamic gas flow is the flow of a gas with comparably large changes of density characterised by high Mach numbers (e.g. supersonic flow in the nozzles of steam jet pumps).

3.3 Viscous flow

The viscous flow is a gas flow 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 is dependent on the viscosity of the gas and may be laminar or turbulent. For the viscous flow, the flow resistance is dependent on the pressure.

3.3.1 Turbulent flow

The turbulent flow is a viscous flow with mixing movement above a critical Reynolds number *Re* (for circular-cylindrical pipes, $Re \approx 2300$).

3.3.2 Laminar flow

The laminar flow (layer- or thread flow) is viscous flow without mixing movements at small Reynolds numbers.

3.3.2.1 Poiseuille flow

The Poiseuille flow is the particular case of laminar flow in a long pipe with a circular-cylindrical cross-section. In that case, a parabolic velocity distribution occurs.

3.4 Molecular flow

The molecular flow is a gas flow 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. For the molecular flow, the flow resistance is independent of the pressure.

3.5 Intermediate flow

The intermediate flow is a gas flow in the range between viscous flow and molecular flow.

3.6 Molecular effusion

The molecular effusion is a gas flow from an aperture in a wall having a negligible thickness, the largest dimension of the aperture being smaller than the mean free path.

3.7 Thermal transpiration

The thermal transpiration is a gas flow in the molecular flow range through a duct system between two vessels in which different temperatures prevail. It results in a state of equilibrium in which a pressure difference is maintained between the two vessels.

3.8 pV throughput

The pV throughput is the quotient of the pV value of a gas flowing through a transverse section of a duct during a time interval at the respectively prevailing temperature, and the time interval (see also "*Saugleistung* [= throughput]", DIN 28 400 Part 2).

3.9 Mass flow rate

The mass flow rate is the quotient of the mass of a gas flowing through a transverse section of a duct during a time interval, and the time interval.

3.10 Volume flow rate

The volume flow rate is the quotient of the volume of a gas flowing through a transverse section of a duct during a time interval at the respectively prevailing pressure and temperature, and the time interval (see also "*Saugvermögen* [= volume flow rate]" DIN 28 400 Part 2).

3.11 Molar flow rate

The molar flow rate is the quotient of the amount of substance of a gas flowing through a transverse section of a duct during a time interval, and the time interval.

3.12 Molecular flow rate; molecular flow

The molecular flow rate through a given surface element is the quotient of the difference between the average number of molecules which flow through the surface element in one direction during a time interval, and the average number of molecules which flow through the surface element in the opposite direction, and the time interval.

3.12.1 Molecular flow rate density; density of molecular flux

The molecular flow rate density is the quotient of the molecular flow rate through a surface element, and the content of the surface element.

3.13 Transmission probability (in molecular flow)

The transmission probability is the probability that a gas molecular which enters the inlet aperture of a duct element in any direction leaves the duct element through the outlet aperture without having again passed the inlet aperture in the opposite direction. In this regard, according to Clausing, the cosine law is assumed for the interaction with the walls.

3.14 Conductance

The conductance of an orifice in a thin wall or a duct or part of a duct between two specified cross-sections is the quotient of the pV throughput and the difference in pressures prevailing on both sides of the opening or duct or part of a duct on the two specified cross-sections, assuming isothermal conditions in the system.

3.15 Intrinsic conductance

The intrinsic conductance is the conductance for the case that the orifice or duct connects two vessels, in each of which a Maxwell-Boltzmann speed distribution prevails, or else there would be no gas flow.

Note: The intrinsic conductance is a characteristic value of the component.

3.16 Resistance

The resistance is the reciprocal value of the conductance.

3.17 Intrinsic resistance

The intrinsic resistance is the reciprocal value of the intrinsic conductance.

4 Terms and definitions from surface and solid state physics

Note: within this section, the term “molecules” refers to neutral and charged molecules without consideration of their applicability to the kinetic theory of gases.

4.1 Sorption

Sorption is the binding of gas (sorbate) by a solid or liquid (sorbent). Sorbents are also referred to as sorption media.

4.2 Adsorption

Adsorption is sorption in which the gas (adsorbate) is bound on the surface of the solid or liquid (adsorbent).

4.2.1 Physical adsorption

Physical adsorption is an adsorption caused by physical forces which does not result in certain chemical compounds.

4.2.2 Chemical adsorption

Chemical adsorption is adsorption resulting in chemical compounds.

4.3 Absorption

Absorption is sorption in which the gas (absorbate) penetrates within the solid or liquid (absorbent).

4.4 To getter

Gettering is binding of gas, preferably through chemical reactions. In many cases, getters (gettering substances) have large real surfaces (see DIN 28 400 Part 6).

4.5 Clean-up of gases by an electrical discharge

The clean-up of gases by an electrical discharge is sorption as a result of an electrical gas discharge.

4.6 Occlusion

Occlusion is the encapsulation of gas quantities in solids or liquids.

4.7 Accommodation factor

The accommodation factor is the quotient of the average amount of energy which molecules impinging on a surface exchange with the surface, and the average amount of energy which would be exchanged in the same time interval if the molecules reach the precise temperature of the surface – i.e. if their speeds when leaving the surface correspond to a Maxwell-Boltzmann distribution appertaining to the temperature of the surface.

4.8 Area-related impingement rate

The area-related impingement rate is the quotient of the number of molecules impinging upon a surface during a time interval, and the product of the time interval and the area of the surface.

4.9 Area-related condensation rate

The area-related condensation rate is the quotient of the number of molecules which condense on a surface during a time interval, and the product of the time interval and the area of the surface. [3]

[3] Analogous definitions relating to substance amounts of masses are permissible.

4.10 Condensation probability

The condensation probability is the quotient of the condensation rate and the impingement rate in relation to the same area.

4.11 Area-related sticking rate

The area-related sticking rate is the quotient of the number of molecules which are adsorbed on a surface during a time interval, and the product of the time interval and the area of the surface. [4]

4.12 Sticking probability

The sticking probability is the quotient of the sticking rate and the impinging rate, in relation to the same area.

4.13 Residence time

The residence time is the average time interval during which a molecule resides on the surface in the adsorbed state.

4.14 Surface migration

The surface migration is the movement of molecules on a surface. The surface migration of a liquid film is referred to as creeping.

4.14.1 Surface diffusion

The surface diffusion is a surface migration owing to a gradient of the chemical potential, e.g. due to a concentration gradient.

4.15 Desorption

Desorption is the release of sorbed gases from a sorbent. The release may be spontaneous or accelerated by physical processes.

4.15.1 Outgassing

Outgassing is spontaneous desorption.

4.15.2 Degassing

Degassing is desorption accelerated by means of physical processes.

4.16 Area-related desorption rate

The area-related desorption rate is the quotient of the pV throughput (or molecular flow rate) released at a given point in time – spontaneously or accelerated by physical processes – from a sorbent, and the area of the geometric surface of the sorbent.

Note: The same applies for the area-related outgassing rate and the area-related degassing rate.

4.17 Area-related evaporation rate

The area-related evaporation rate is the quotient of the number of molecules which evaporate from a surface during a time interval, and the product of the time interval and the area of the surface. [5]

4.18 Effective evaporation rate

The effective evaporation rate is the evaporation rate reduced by the concentration rate, in relation to the same area.

4.19 Gas diffusion

Gas diffusion is the movement of a gas owing to its concentration gradient in another medium. The medium may be gaseous, liquid or solid.

4.19.1 Diffusion coefficient; diffusivity

The diffusion coefficient is the absolute amount of the quotients of the molecular flow rate density and the concentration gradients. The molecular flow rate relates to a surface element perpendicular to the direction of the gradient.

4.20 Permeation

Permeation is the passage of a gas through a solid or liquid of finite (wall) thickness. This process includes diffusion and surface effects.

4.20.1 Permeability

Permeability is a guide value for permeation which states how large the pV throughput is through a solid or liquid of finite thickness if a particular pressure gradient prevails between the two sides of the solid or liquid.

Note: permeability contains substance-specific and geometric properties of the body in question: it is temperature-dependent.

4.20.2 Permeability coefficient

The permeability coefficient is the factor of permeability dependent upon the substance and surface quality.

Note: also referred to as permeation conductivity.

---

[4] See page 5

[5] See page 5

List of keywords

The numbers after the keywords are the section numbers.

A

Absolute vacuum 1.2
Absorption 4.3
Accommodation factor 4.7
Adsorption 4.2
Adsorption, physical 4.2.1
Area-related collision rate 2.4.2
Area-related condensation rate 4.9
Area-related degassing rate 4.16
Area-related desorption rate 4.16
Area-related evaporation rate 4.17
Area-related impingement rate 4.8
Area-related outgassing rate 4.16
Area-related sticking rate 4.11
atm, see table in Supplementary Sheet 1 to DIN 28 400
Average speed of molecules 2.2.1

B

bar, see table in Supplementary Sheet 1 to DIN 28 400

C

Chemical adsorption 4.2.2
Clean-up of gases by an electrical discharge 4.5
Collision rate 2.4
    Collision rate, area-related 2.4.2
    Collision rate, volume-related 2.4.1
Concentration of molecules of a given component *i* in a mixture of gas 2.1.1
Condensation probability 4.10
Condensation rate, area-related 4.9
Conductance 3.14
    Intrinsic conductance 3.15
Creeping 4.14

D

Degassing 4.15.2
Degassing rate, area-related 4.16
Density
    Concentration of molecules of a given component *i* in a mixture of gas 2.1.1
    Molecular flow rate density 3.12.1
    Number density of molecules 2.1
Desorption 4.15
Desorption rate, area-related 4.16
Diffusion
    Diffusion coefficient 4.19.1
    Gas diffusion 4.19
    Surface diffusion 4.14.1
Diffusion coefficient 4.19.1
Dynamic gas flow 3.2

E

Effective evaporation rate 4.18
Effusion
    Molecular effusion 3.6
    Thermal transpiration 3.7
Evaporation rate, area-related 4.17
Evaporation rate, effective 4.18

F

Flow
    Dynamic gas flow 3.2
    Intermediate flow 3.5
    Laminar flow 3.3.2
    Molecular effusion 3.6
    Molecular flow 3.4
    Poiseuille flow 3.3.2.1
    Thermal transpiration 3.7
    Turbulent flow 3.3.1
    Viscous flow 3.3
Flow rate
    Mass flow rate 3.9
    Molar flow rate 3.11
    Molecular flow rate 3.12
    Molecular flow rate density 3.12.1
    pV throughput 3.8
    Volume flow rate 3.10
Flow rate, molar 3.11
Free path, mean 2.3

G

Gas (general), see also 1.9 1.8
Gas diffusion 4.19
Getter, to 4.4

H

High vacuum, HV 1.3

I

Ideal vacuum 1.2
Impingement rate, area-related 4.8
Intermediate flow 3.5
Intrinsic conductance 3.15
Intrinsic resistance 3.17

L

Laminar flow 3.3.2

M

Mass flow rate 3.9
Mean free path 2.3
Medium vacuum 1.3
millibar, mbar, see also table in Supplementary Sheet 1 to DIN 28 400 1.5
Molar flow rate 3.11

Molar volume of a gas 1.8.3
Molecular effusion 3.6
Molecular flow 3.4, 3.12, 3.13, 2.5
Molecular flow rate 3.12
Molecular flow rate density 3.12.1
Molecules, see Notes in sections 2 and 4
Monolayer time 2.5
Most probable speed 2.2.2
N
Number density of molecules 2.1
O
Occlusion 4.6
Outgassing 4.15.1
Outgassing rate, area-related 4.16
P
Partial pressure 1.6
Pascal, Pa, see also table in Supplementary Sheet 1 to DIN 28 400 1.5
Path, mean free 2.3
Permeability 4.20.1
Permeability coefficient 4.20.2
Permeation 4.20
Permeation conductivity 4.20.2
Physical adsorption 4.2.1
Poiseuille flow 3.3.2.1
Pressure 1.4
- Partial pressure 1.6
- Pressure units, see also table in Supplementary Sheet 1 to DIN 28 400 1.5
- Saturation vapour pressure 1.10
- Total pressure 1.7

Pressure units, see also table in Supplementary Sheet 1 to DIN 28 400 1.5
pV throughput 3.8
Q
Quantity of gas (pV value) 3.1
R
Ranges of vacuum, see also Table 1 1.3
Residence time 4.13
Resistance 3.16
- Intrinsic resistance 3.17

Root mean square speed of molecules 2.2.3
Rough (low) vacuum 1.3
S
Saturated vapour 1.9
Saturation vapour pressure 1.10
Sorption 4.1
- Absorption 4.3
- Adsorption 4.2
- Chemical adsorption 4.2.2
- Clean-up of gases by an electrical discharge 4.5
- Getter, to 4.4
- Physical adsorption 4.2.1

Speed of molecules 2.2
- Average speed of molecules 2.2.1
- Most probable speed 2.2.2
- Root mean square speed of molecules 2.2.3

Standard conditions of a gas 1.8.1
Standard volume of a gas 1.8.2
Sticking probability 4.12
Sticking rate, area-related 4.11
Surface collision rate 2.4.2
Surface diffusion 4.14.1
Surface migration 4.14
T
Thermal transpiration 3.7
Torr, see table in Supplementary Sheet 1 to DIN 28 400
Total pressure 1.7
Transmission probability 3.13
Transpiration, thermal 3.7
Turbulent flow 3.3.1
U
Ultra-high vacuum, UHV 1.3
Unsaturated vapour 1.9
V
Vacuum 1.1
- High vacuum 1.3
- Medium vacuum 1.3
- Rough (low) vacuum 1.3
- Ultra-high vacuum 1.3

Vacuum, absolute 1.2
Vacuum, ideal 1.2
Vapour 1.9
- Saturated vapour 1.9
- Saturation vapour pressure 1.10
- Unsaturated vapour 1.9

Viscous flow 3.3
Volume collision rate 2.4.1
Volume flow rate 3.10
Volume-related collision rate 2.4.1

Cited standards and other documents

DIN 1301 Part 1	Units, names, symbols
DIN 1343	Reference conditions, normal conditions, normal volume, concepts and values
DIN 28 400 Part 2	Vacuum technology, Terms and Definitions, Vacuum pumps
DIN 28 400 Part 6	Vacuum technology, Terms and Definitions, Surface analysis techniques
ISO 3529-1 1981	Vacuum technology, Vocabulary, Part 1, General terms
Supplementary Sheet 1	
to DIN 28 400	Vacuum technology, Terms and Definitions, Alphabetical list of keywords

Earlier editions

DIN 28 400 Part 1: 05.61, 01.72, 07.79

Amendments

The following amendments have been made compared to the July 1979 edition:

a) Sub-sections expanded and deleted

b) Revised in terms of the standards and adapted to technical development

Explanations

This standard contains terms and definitions of physical technical terms which are general terms in vacuum technology. The terms are comparable to those in International Standard ISO 3529-1:1981 Vacuum technology – Vocabulary, Part 1: General terms.

International Patent Classification

G 01 F

G 01 L