
**Vacuum technology — Standard
methods for measuring vacuum-pump
performance —**

**Part 1:
General description**

*Technique du vide — Méthodes normalisées pour mesurer les
performances des pompes à vide —
Partie 1: Description générale*

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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

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Contents

	Page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols and abbreviated terms	3
5 Test methods	4
5.1 Volume flow rate (pumping speed) measurement by the throughput method	4
5.1.1 General	4
5.1.2 Test dome for the throughput method	5
5.1.3 Experimental setup	6
5.1.4 Determination of the volume flow rate	7
5.1.5 Measuring procedure	8
5.1.6 Measuring uncertainties	8
5.1.7 Evaluation of the measurement	8
5.2 Volume flow rate (pumping speed) measurement by the orifice method	9
5.2.1 General	9
5.2.2 Test dome for the orifice method	9
5.2.3 Experimental setup	10
5.2.4 Determination of the volume flow rate	11
5.2.5 Measuring procedure for the orifice method	12
5.2.6 Adjustment of the pressure-measuring gauges	12
5.2.7 Measurement of the volume flow rate	12
5.2.8 Measuring uncertainties	12
5.2.9 Evaluation of the measurement	13
5.3 Volume flow rate (pumping speed) measurement by the pump-down method	14
5.3.1 General	14
5.3.2 Test dome for the pump-down method	14
5.3.3 Quick-acting valve	15
5.3.4 Experimental setup	15
5.3.5 Determination of the volume flow rate	16
5.3.6 Measuring procedure	17
5.3.7 Limits of applicability	18
5.3.8 Evaluation of the measurement	18
5.3.9 Measurement uncertainty	18
5.4 Measurement of the base pressure	18
5.4.1 Operating conditions	18
5.4.2 Test procedure for pumps with a base pressure $>10^{-4}$ Pa	19
5.4.3 Test procedure for pumps with a base pressure $<10^{-4}$ Pa	19
5.4.4 Evaluation of the measurement	19
5.5 Measurement of the compression ratio and the critical backing pressure	19
5.5.1 Experimental setup	20
5.5.2 Determination of the compression ratio and the critical backing pressure	20
5.5.3 Measurement procedure	21
5.5.4 Measurement uncertainty	22
5.5.5 Evaluation of the measurements	22
5.5.6 Specific recommendations for extremely high compression ratio measurements	22
Annex A (informative) Mean free path of some important gases	24
Annex B (informative) Measuring uncertainties	25
Bibliography	28

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 (see 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 (see www.iso.org/patents).

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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 21360-1:2012), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

- Note in [3.3](#) has been deleted;
- K_0 in [3.7](#) has been corrected;
- [3.9](#) the definition of the volume has been changed to "is the volume of transported gas";
- [Figure 1](#) has been corrected;
- [Figure 2](#) has been corrected;
- [5.2.7](#): change to "for at least 60s" instead of " for the following minute".

A list of all parts in the ISO 21360 series can be found on the ISO website.

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

This document is a basic standard for measuring the performance data of vacuum pumps. The methods specified here are well known from existing national and International Standards. In developing this document, the aim has been to provide a single document containing the measurements of performance data of vacuum pumps and to simplify the future development of specific vacuum pump standards.

Specific vacuum pump standards will contain a suitable selection of measurement methods from this document in order to determine the performance data, limiting values and specific operational conditions on the basis of the specific properties of the particular kind of pump. Whenever a discrepancy exists between this document and the specific standard, it is the specific standard which is valid.

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Vacuum technology — Standard methods for measuring vacuum-pump performance —

Part 1: General description

1 Scope

This document specifies three methods for measuring the volume flow rate and one method each for measuring the base pressure, the compression ratio, and the critical backing pressure of a vacuum pump.

The first method for measuring the volume flow rate (the throughput method) is the basic concept, in which a steady gas flow is injected into the pump while the inlet pressure is measured. In practice, the measurement of gas throughput may be complicated or inexact. For this reason, two other methods are specified which avoid the direct measurement of throughput.

The second method for measuring the volume flow rate (the orifice method) is used when there is very small throughput at very small inlet pressures (under a high or ultra-high vacuum). It is based on measuring the ratio of pressures in a two-chamber test dome in which the two chambers are separated by a wall with a circular orifice.

The third method for measuring the volume flow rate (the pump-down method) is well suited for automated measurement. It is based on the evacuation of a large vessel. The volume flow rate is calculated from two pressures, before and after a pumping interval, and from the volume of the test dome. Different effects, such as leak and desorption rates, gas cooling by nearly isentropic expansion during the pumping interval, and increasing flow resistance in the connection line between test dome and pump caused by molecular flow at low pressures, influence the results of the pressure measurement and the resulting volume flow rate.

The choice of the required measurement methods depends on the properties of the specific kinds of vacuum pump, e.g. the measurement of the critical backing pressure is only necessary for vacuum pumps which need a backing pump. All data that are measured on a vacuum pump, but not specified in this document (e.g. measurement of power consumption), are defined in the specific pump standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3529-2, *Vacuum technology — Vocabulary — Part 2: Vacuum pumps and related terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3529-2 and the following 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 volume flow rate

$$q_V = \frac{dV}{dt} \text{ where}$$

V is volume;

t is time

[SOURCE: ISO 80000-4:2006^[4], 4-30]

EXAMPLE In the context of this document, the volume flow rate is the volume of gas which, under ideal conditions, flows from the test dome through the pump inlet per time.

Note 1 to entry: For practical reasons, the volume flow rate of a given pump and for a given gas is conventionally considered to be equal to the quotient of the throughput of this gas and of the equilibrium pressure at a given location. The volume flow rate is expressed in cubic metres per hour or litres per second.

Note 2 to entry: The term “pumping speed” and symbol “ S ” are often used instead of “volume flow rate”.

3.2 inlet pressure

p_1, p_d, p_e
pressure at the inlet of the pump, measured at a defined location in the test dome

3.3 base pressure

p_b
pressure obtained in the test dome after conditioning the vacuum pump and the test dome

Note 1 to entry: See 5.4.

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3.4 maximum working pressure

$p_{1\max}$
highest pressure on the inlet side that the vacuum pump and the driving device can withstand for a prolonged period of operation time without being damaged

3.5 backing pressure

p_3
pressure at the outlet of a vacuum pump

3.6 critical backing pressure

p_c
maximum backing pressure for which the conditions are defined in the instruction manual or in a specific standard for the particular vacuum pump

3.7 compression ratio

K_0
compression ratio without gas load, wherein p_{b3} is the base pressure of the backing pump and p_{b1} is the base pressure of the test pump

$$K_0 = \frac{p_3 - p_{b3}}{p_1 - p_{b1}}$$

3.8**test dome**

special vacuum vessel with precisely defined size, diameter and connection flanges on specified locations, used for standard performance data measurements on vacuum pumps

3.9**throughput** Q

amount of gas flowing through a duct, expressed by the formula:

$$Q = \frac{p_1 V}{t} = p_1 q_V$$

where

p_1 is the (high) vacuum pressure on the inlet;

q_V is the volume flow rate of the test pump;

t is time;

V is the volume of transported gas

3.10**standard gas flow rate** q_{Vstd}

volume flow rate at standard reference conditions, i.e. 0 °C and 101 325 Pa

4 Symbols and abbreviated terms

Symbol	Designation	Unit
a	inner diameter of the connection pipe between test pump and quick-acting valve (items 3 and 5 in Figure 6)	m
A	cross-section of the connection pipe between test pump and quick-acting valve (items 3 and 5 in Figure 6)	m ²
C	conductance	m ³ /s (= 10 ³ l/s)
d	diameter of orifice	m
D	inner diameter of test dome	m
D_i	diameter of the inlet pipe	m
D_N	nominal diameter of test dome	m
K_0	compression ratio of vacuum pump with zero throughput	—
l	length of the connection pipe between test pump and quick-acting valve (items 3 and 5 in Figure 6)	m
\bar{l}	mean free path	m
M	molar mass of gas	kg/mol
p_0	standard atmospheric pressure — 101 325 Pa	Pa

p_1	(high) vacuum pressure on inlet	Pa (or mbar)
$p_{1\max}$	maximum working pressure on inlet	Pa (or mbar)
p_3	vacuum pressure in backing line	Pa (or mbar)
$p_{t_1}, p_{t_2}, p_{t_3}$	pressures in the test dome for the pump-down method, measured before and after time intervals $\Delta t_1, \Delta t_2, \Delta t_3$	Pa (or mbar)
p_{b1}, p_{b2}, p_{b3}	base pressures	Pa (or mbar)
p_c	critical backing pressure	Pa (or mbar)
p_d, p_e	pressures in the test dome for the orifice method	Pa (or mbar)
Q	gas throughput of vacuum pump	Pa·l/s (or mbar·l/s)
Q_r	test gas load	Pa·l/s (or mbar·l/s)
q_V	volume flow rate of test pump	l/s (or m ³ /h)
q_{VBP}	volume flow rate of backing pump	l/s (or m ³ /h)
q_{Vscm}	volume flow rate at standard reference conditions for gases, i.e. 0 °C and 101 325 Pa	sccm (or cm ³ /min)
q_{Vstd}	volume flow rate at standard reference conditions for gases, i.e. 0 °C and 101 325 Pa	l/s (or m ³ /h)
Q_{\max}	maximum gas throughput of vacuum pump which the pump can withstand without damage	Pa·l/s (or mbar·l/s)
R	ideal gas constant	8,314 J/(mol·K)
T	thermodynamic temperature	K
T_0	273,15 K (defined as 0 °C)	K
T_D	temperature of the test dome	K
T_f	temperature of the flow meter	K
u	measurement uncertainty	—
V	volume of the test dome	l, m ³
V_i	volume of connection pipe between test pump and quick-acting valve (items 3 and 5 in Figure 6)	l, m ³
δ	thickness of the orifice wall at the orifice diameter	m

5 Test methods

5.1 Volume flow rate (pumping speed) measurement by the throughput method

5.1.1 General

The throughput method is the one most used for vacuum pumps and is applicable to all pressure ranges and pump sizes where flow meters for gas throughput measurements are available with sufficient

accuracy. The gas flow measuring ranges shall be chosen by multiplying the expected volume flow rate by the maximum and minimum working pressure of the test pump.

All measuring devices shall be calibrated either:

- a) in a traceable way to a vacuum primary or to a national standard, or
- b) by means of instruments of absolute measure which are traceable to the SI units and to which measurement uncertainties can be attributed.

In the case of calibrated measuring instruments, there should exist a calibration certificate in accordance with ISO/IEC 17025[3].

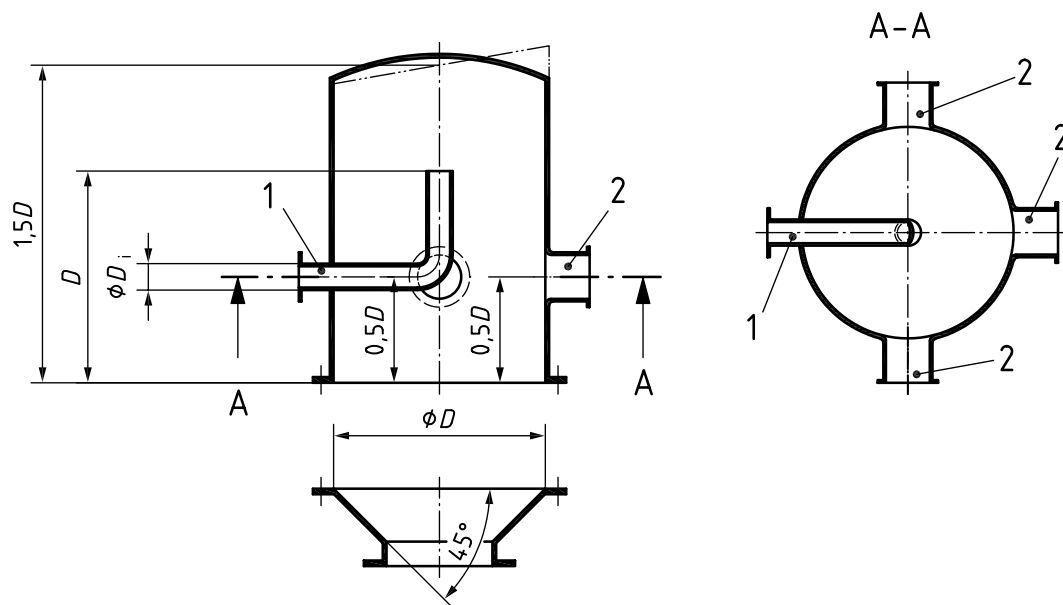
5.1.2 Test dome for the throughput method

For these measurements, use a test dome as shown in [Figure 1](#) with the same nominal diameter, D_N , as that of the pump inlet. The face of the dome opposite the inlet flange may be flat, conical or slightly curved, with the same average height above the flange as the flat face. Three flanges are preferable for pressure measurement at a height of $D/2$ above the bottom flange if more than one pressure gauge is used. The diameter of these flanges should be greater than or equal to the flanges of the gauges used, and their mounting dimensions shall be noted. No measuring port shall be located in the angle range $\pm 45^\circ$ next to a gas inlet port. The connection pipes between flange and dome shall not protrude beyond the dome wall on the inside, with the exception of the gas inlet pipe.

If necessary for the test pump, the test dome shall be fitted with a device for bake-out that ensures uniform heating of the dome to achieve the base pressure.

The volume of the test dome may depend on the pump type. Refer to the specific pump standard for details.

For pumps with an inlet flange diameter of less than $D_N = 100$ mm, the diameter of the dome shall correspond to $D_N = 100$ mm. The transition to the pump inlet flange shall be made through a 45° conical adaptor, as shown in [Figure 1](#).



Key

- 1 gas inlet pipe and temperature measuring point for T_D
- 2 vacuum gauge and mass spectrometer connections
- D_i diameter of the inlet pipe
- D inner diameter of test dome, in metres

NOTE D_i should be big enough to allow homogenous gas conditions at the pump flange. A diameter of $0,1D$ is generally appropriate.

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Figure 1 — Test dome for the throughput method
 46843447/682/iso-21360-1-2020

5.1.3 Experimental setup

See [Figure 2](#).

The test dome shall be clean and dry. The cleanness of the pump, seals and other components shall be appropriate for the expected base pressure. All components are mounted together under clean conditions in accordance with [Figure 2](#). Because of the narrow measuring range, flow meters with different ranges may be switched in series. If flow is restricted by a small flow meter, they may be used in parallel with a manifold, adding a valve between every flow meter and the manifold. Instead of the flow meter and the gas inlet valve, mass flow controllers with programmable throughputs may be used. They shall be combined in parallel on a manifold.

The leak-tightness of large mass flow controllers is not sufficient in many cases. In such cases, it is advisable that valves be used between the flow controller and the manifold.

Ionization gauges and mass spectrometers shall be installed in such a way that there is no direct geometrical path between them.

CAUTION — Observe the safety instructions of the vacuum pump manufacturer.