INTERNATIONAL STANDARD

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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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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 21360-1 was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.

This first edition of ISO 21360-1 cancels and replaces ISO 21360:2007, of which it constitutes a minor revision.

ISO 21360 consists of the following parts, under the general title *Vacuum technology — Standard methods for measuring vacuum-pump performance*:

— *Part 1: General description*

— *Part 2: Positive displacement vacuum pumps*

Introduction

This part of ISO 21360 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 part of ISO 21360, 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 part of ISO 21360 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 part of ISO 21360 and the specific standard, it is the specific standard which is valid.

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

Part 1: General description

1 Scope

This part of ISO 21360 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 part of ISO 21360 (e.g. measurement of power consumption), are defined in the specific pump standard.

2 Normative references

The following referenced documents are indispensable for the application 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.

3.1
volume flow rate
q_V

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

where

V is volume;

t is time

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

EXAMPLE In the context of this part of ISO 21360, 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 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 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

See 5.4.

NOTE The base pressure is the value which the pressure in the test dome approaches asymptotically. It is the lowest pressure obtainable with the pump, but there is no practical method of measurement or specification.

3.4
maximum working pressure
p_{1max}
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
ratio of the backing pressure, p_3, to the inlet pressure, p_1, of the vacuum pump without throughput, expressed by the equation:

$$K_0 = \frac{p_3}{p_1}$$

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 equation:

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

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 the test dome

3.10
standard gas flow rate
$q_{V\text{std}}$
volume flow rate at standard reference conditions, i.e. 0 °C and 101 325 Pa

NOTE Standard reference conditions are defined in ISO 3529-1:1981[1], 1.0.2.

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_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 (defined in ISO 3529-1:1981[1], 1.0.2)	Pa
p_1	(high) vacuum pressure on inlet	Pa (or mbar)

p_{1max}	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 Δt_1, Δt_2, Δt_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_{Vsccm}	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 in ISO 3529-1:1981[1], 1.0.2)	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].

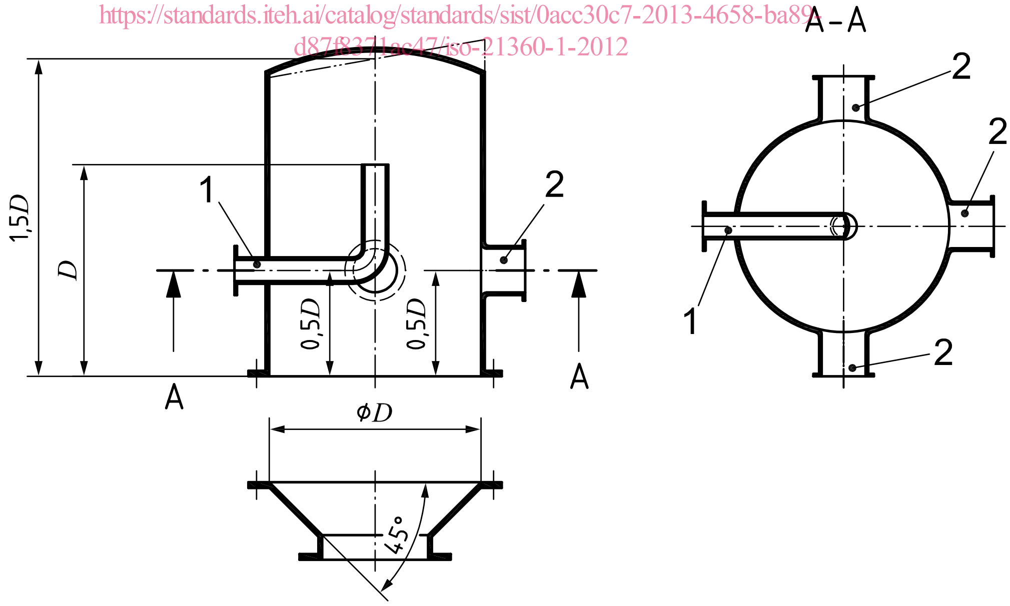
5.1.2 Test dome for the throughput method

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 ±45° 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 inner diameter of test dome, in metres

Figure 1 — Test dome for the throughput method

5.1.3 Experimental setup

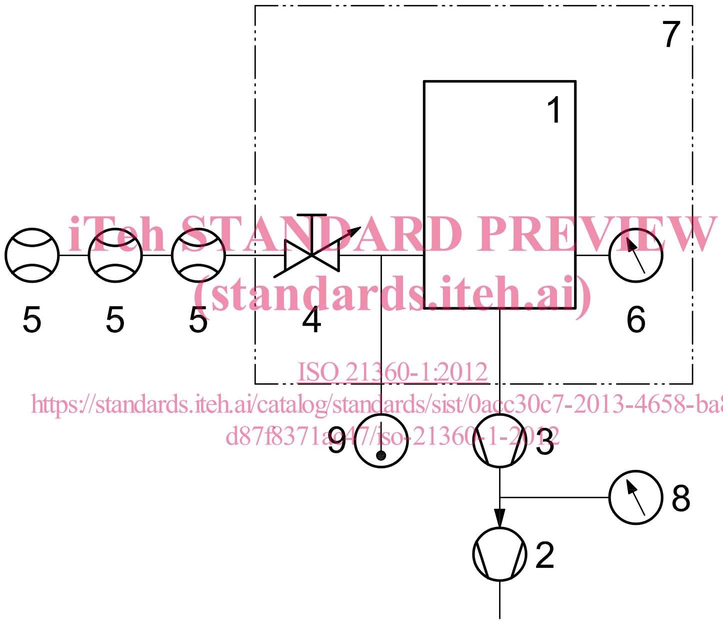
See Figure 2.

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.



Key

1	test dome	4	gas inlet valve	7	heating jacket (optional)
2	backing pump	5	flow meters to measure Q	8	vacuum gauge to measure p_3
3	test pump	6	vacuum gauge to measure p_1	9	temperature measuring point for T_D

NOTE Items 2 and 8 are only used in connection with high-vacuum test pumps.

Figure 2 — Arrangement for measuring volume flow rate (pumping speed) with throughput method

5.1.4 Determination of the volume flow rate

The method adopted for the measurement of the volume flow rate, q_V, is the throughput method for which the gas throughput, Q, is measured outside the dome. If the pressure, p_1, in the test dome, measured by a vacuum

