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

Part 2:
Positive displacement vacuum pumps

Technique du vide — Méthodes normalisées pour mesurer les performances des pompes à vide —

Partie 2: Pompes à vide volumétriques

Reference number
ISO 21360-2:2012(E)

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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 21360-2 was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.

This first edition of ISO 21360-2 cancels and replaces ISO 1607-1:1993 and ISO 1607-2:1989, which have been technically revised.

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 specifies methods for measuring the performance data of positive-displacement vacuum pumps. This part of ISO 21360 complements ISO 21360-1, which provides a general description of the measurement of performance data of vacuum pumps.

The methods described here are well known from existing national and International Standards. The aim in drafting this part of ISO 21360 was to collect together suitable methods for the measurement of performance data of positive-displacement vacuum pumps. This part of ISO 21360 takes precedence in the event of a conflict with ISO 21360-1.

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

Part 2:
Positive displacement vacuum pumps

1 Scope

This part of ISO 21360 specifies methods for measuring the volume flow rate, base pressure, water vapour tolerance, power consumption, and the lowest start-up temperature of positive displacement vacuum pumps, which discharge gas against atmospheric pressure and with a usual base pressure <10 kPa.

In this part of ISO 21360, it is necessary to use the determinations of volume flow rate and base pressure specified in ISO 21360-1.

This part of ISO 21360 also applies to the testing of other types of pumps which can discharge gas against atmospheric pressure, e.g. drag pumps.

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 21360-1:2012, *Vacuum technology — Standard methods for measuring vacuum-pump performance — Part 1: General description*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21360-1 and the following apply.

3.1
gas ballast
gas or air inlet into the swept volume of the pump

3.2
water vapour tolerance
p_{H_2O}
maximum water vapour pressure which can be conveyed by the pump without condensation in the pump

NOTE If there is no problem of water vapour condensation, e.g. when an oil and water separation unit is included, maximum water vapour pressure is acceptable.

3.3
water vapour capacity
mass of water which can be conveyed by the pump without condensation per time

3.4
swept volume
V_{SW}
input volume, which is conveyed by the pump during one cycle

3.5
saturation vapour pressure
p_s
pressure exerted by the vapour of a pure chemical substance in equilibrium with a condensed phase (liquid or solid or both) in a closed system

NOTE For each substance, saturation vapour pressure is a function of temperature only.

3.6
water vapour saturation temperature
temperature corresponding to the water vapour saturation pressure

3.7
compression energy
energy needed to compress a gas volume

4 Symbols and abbreviated terms

Symbol	Designation	Unit
α	pressure-increasing factor to open the exhaust valve	
φ_{H_2O}	relative humidity of air	%
κ	adiabatic exponent	
L	molar evaporation energy	J/mol
P_0	power consumption of the pump at ultimate pressure at specified rotational frequency	W
P_{0B}	power consumption of the pump at ultimate pressure at specified rotational frequency with maximum gas ballast	W
P_{max}	maximum power consumption of the pump at specified rotational frequency	W
p_0	standard atmospheric pressure	Pa
p_2	air partial pressure of exhaust gas	Pa
p_a	water vapour partial pressure in atmosphere	Pa
p_B	air partial pressure in atmosphere	Pa
p_{H_2O}	water vapour tolerance	Pa
p_s	saturation water vapour pressure	Pa
p_{T_0}	saturation water vapour pressure at temperature T_0	Pa
q_V	volume flow rate of the pump	m^3/s
q_{VB}	volume flow rate of the gas ballast duct	m^3/s
R	general gas constant: $R = 8{,}314\ 3$	J/(mol·K)
T_0	temperature corresponding to p_{T_0}	K
T_1	environmental temperature	°C
T_2	exhaust pump temperature	°C

T_{20}	exhaust temperature without throughput	K
T_{2cr}	corrected exhaust pump temperature for water vapour	K
T_{2s}	exhaust saturation temperature dependent on p_1	K
V_2	exhaust volume	m^3
V_B	swept gas ballast volume	m^3
V_{SW}	swept volume	m^3
W_{ad}	adiabatic compression energy	J
$W_{ad,\,H_2O}$	adiabatic compression energy for water vapour	J
W_{ada}	adiabatic compression energy for air	J
W_{cr}	correction factor for the pump exhaust temperature	

5 Test methods

5.1 Measurement of the volume flow rate

5.1.1 Measurement methods

Volume flow rate measurement methods are specified in ISO 21360-1:2012, 5.1 and 5.3. The throughput method or the pump-down method shall be used for the volume flow rate measurement. If no other descriptions or experimental arrangements are shown, those of ISO 21360-1 shall be used.

5.1.2 Throughput method

The standard method is the throughput method. It can be used for all pumps to which this part of ISO 21360 applies.

The volume of the test dome shall be $\geq 2V_{SW}$, where V_{SW} is the swept volume, for rotary plunger-type and fixed vane-type vacuum pumps. The volume of the test dome shall be $\geq 5V_{SW}$ for other types of vacuum pump. The type of test dome shall be in accordance with ISO 21360-1.

The transition to the pump inlet flange shall be made through a 45° conical adaptor, as shown in ISO 21360-1:—, Figure 1, if the inlet flange diameter, D_N, is less than the inner diameter, D, of the test dome for positive displacement-type vacuum pumps.

5.1.3 Pump-down method

The pump-down method is suitable for smaller pumps (e.g. up to 0,01 m^3/s), because a large test dome is required. The volume of the test dome shall be larger than the expected maximum volume flow rate, in cubic metres per second, multiplied by a factor of 120 s.

5.1.4 Operating conditions

The pump shall be connected to the equipment shown in the experimental setup and switched on. Before taking the measurements, the pump should be operated until it has reached its normal operational temperature. The rotational frequency (“speed”) shall not deviate by more than ±3 % from the nominal frequency.

If the test pump has a gas ballast device, the volume flow rate shall first be measured without and then with gas ballast.

The environmental conditions shall be in accordance with ISO 21360-1.

5.2 Measurement of the base pressure

The measurement of the base pressure is specified in ISO 21360-1:2012, 5.4. It is measured with the same experimental setup as specified in ISO 21360-1:2012, Clause 5. The measurement shall be done first without and later with gas ballast. The measurements can be carried out in random order when the order has no influence on them.

5.3 Measurement of water vapour tolerance

Water vapour tolerance is specified as the maximum pure-water vapour pressure at the input of the pump. Several methods of water vapour tolerance measurement, in pascals, have been reported. An example of the measurement method of water vapour tolerance is given in Annex A.

Several methods of water vapour capacity measurement, in kilograms per second, have been reported. An example of the conversion between water vapour tolerance and water vapour capacity values is shown in Reference [1], p. 331.

See also Reference [1], p. 329-333, and Reference [2], p. 60.

5.4 Determination of the power consumption

5.4.1 General

The power consumption of the pump varies with the inlet pressure and is different if gas ballast is used. The power consumption should be measured for the following operating conditions: at base pressure, with and without gas ballast, and at maximum power consumption, with the corresponding inlet pressure. Maximum power consumption is reached when the pump is operated at the maximum electrical power needed.

NOTE There are some pumps which cannot be operated at maximum power consumption continuously.

5.4.2 Measuring conditions

The rotational frequency should be in the range given by the manufacturer. If no limits are defined, it should not deviate more than ±3 % from the specified rotational frequency.

5.4.3 Measuring procedure

Install an electrical-power measuring device between the mains power and the pump or the power supply. Measure the real power consumption using this device. If the pump has an electronic power supply, frequency filters are allowed.

First, operate the pump, filled with any lubrication specified by the manufacturer, for 1 h with both the inlet valve and gas ballast valve closed. Then measure the power consumption three times over a period of 15 min. The power consumption for the base pressure, P_0, is the mean of these three values.

Measure the power consumption at base pressure for the specified range of continous operation with gas ballast, P_{0B}, with the gas ballast valve open, after the pump has reached its temperature equilibrium. Then measure the power consumption three times over a period of 15 min. The power consumption for the base pressure with the gas ballast valve open, P_{0B}, is the mean of these three values.

After that, operate the pump for the period specified by the manufacturer. Then measure the maximum power consumption in typical operation modes and at different rotational frequencies, including the mode of maximum power consumption. Measure the power consumption three times over a period of 15 min. The maximum power consumption, P_{max}, is the maximum of these three measurements. If the range of operation is specified, measure P_{max} in the specified range.

The value of current should also measured be in a similar fashion to the power consumption.

5.5 Lowest start-up temperature

The lowest pump temperature is that at which the pump can be started with the vented inlet using the motor provided. Cool the vacuum pump, filled with any lubrication specified by the manufacturer, down to the lowest start-up temperature specified by the manufacturer. If no start-up temperature is specified, cool to 12 °C. Before beginning the measurement, measure the pump temperature. If electronics are used in connection with the pump, make sure that no water vapour condenses on these parts.

Then start the pump; it should reach 80 % of its nominal rotational frequency within 10 min.

For pumps specified to start under vacuum at the inlet, the start-up temperature should be ≤18 °C.

5.6 Measuring uncertainties

Measuring uncertainties shall be determined in accordance with ISO 21360-1.