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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 21360-2:2020(E)

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# Foreword

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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).

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This document was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.



This second edition cancels and replaces the first edition (ISO 21360-2:2012), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— Note added to 3.2 and 3.3. The test report should contain the ambient conditions.

— In A.1.5, the formula has been corrected to $p_a = \frac{\varphi_{H_2O}}{100} p_S(T_1)$.

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 specifies methods for measuring the performance data of positive-displacement vacuum pumps. This document 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 document was to collect together suitable methods for the measurement of performance data of positive-displacement vacuum pumps. This document 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 document 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 document, it is necessary to use the determinations of volume flow rate and base pressure specified in ISO 21360-1.

This document 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 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 21360-1:2020, *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.

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**
**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 1 to entry: 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.

Note 2 to entry: The test report should contain the ambient conditions.

 

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

Note 1 to entry: The test report should contain the ambient conditions

**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 1 to entry: For each substance, saturation vapour pressure is a function of temperature only.

**3.6**
**water vapour saturation temperature**
temperature corresponding to the water *saturation vapour pressure* (3.5)

**3.7**
**compression energy**
energy needed to compress a gas volume



## 4 Symbols and abbreviated terms

| Symbol | Designation | Unit |
|---|---|---|
| $\alpha$ | pressure-increasing factor to open the exhaust valve | |
| $\varphi_{H_2O}$ | relative humidity of air | % |
| $\kappa$ | 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 21360-1:2020, 5.1, 5.2 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 document applies.

The volume of the test dome shall be ≥2$V_{SW}$, 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 ≥5$V_{SW}$ 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 21360-1:2020, 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 21360-1:2020, 5.4. It is measured with the same experimental setup as specified in ISO 21360-1:2020, 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 continuous 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 be measured 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.