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

Part 6: Cryo vacuum pumps

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

Partie 6: Pompes à vide cryogéniques

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Contents

Page

Foreword

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

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 cryogenic vacuum pumps. This document complements ISO 21360-1, which provides a general description of the measurement of performance data of 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 6: Cryo vacuum pumps

1 Scope

This document specifies methods for measuring the volume flow rate, maximum throughput, pumping capacity, base pressure cryogenic vacuum pump, cooldown time and crossover value of Cryogenic vacuum pumps.

It is applicable to two-stage, closed-loop gaseous helium cryogenic vacuum pumps, which can be directly flanged to a vacuum chamber.

The cryogenic vacuum pump can capture nitrogen (alternatively dry air), argon, hydrogen and other gases to obtain high/ultra-high vacuum.

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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
base pressure cryogenic vacuum pump
p_b
pressure obtained in the test dome within 24 h of completing cooldown

Note 1 to entry: It is possible that the base pressure is not the lowest pressure obtainable with the cryogenic vacuum pump. The base pressure represents the lowest pressure that can be obtained after reasonable conditioning of the cryogenic vacuum pump and the test dome without any test gas (see 5.5).

Note 2 to entry: For many practical applications (e.g. only cool down time is tested, see 5.6), base pressure also can be obtained in the cryogenic vacuum pump with a blank off flange at the entrance.

3.2
cooldown time
time elapsed between starting the cryogenic vacuum pump at room temperature (293 K ± 3 K) at a starting pressure as indicated by the manufacturer and the point at which the temperature of the *second stage* (3.6) reaches 20 K

Note 1 to entry: The roughing valve should only be closed when the action of closing does not cause the pressure in the cryogenic vacuum pump to rise to a value above the starting pressure.

3.3
crossover value
q_{cv}
maximum amount of nitrogen gas which can be admitted into the pump over a short time with the temperature of the *second stage* (3.6) remaining ≤20 K during the test gas flow

3.4
pumping capacity
q_{pc}
quantity of gas, which has been pumped up to the moment when the volume flow rate has reduced to 50 % of the initial value measured

Note 1 to entry: After having pumped this amount of gas, the pump still can reduce the pressure in the test dome down to a value of $p \leq 10^{-3}$ Pa in less than 10 min to ensure that a certain pumping performance is still available.

3.5
maximum throughput
Q_{max}
maximum quantity of condensable gas flow, which a cryogenic vacuum pump can pump

3.6
second stage
lower temperature side cooling station with the cold panels of a closed-loop, two-stage gaseous helium cold head

4 Symbols

Symbol	Designation	Unit
Q	gas throughput of cryogenic vacuum pump	$Pa \cdot l \cdot s^{-1}$(or $Pa \cdot m^3 \cdot s^{-1}$)
Q_{max}	maximum throughput	$Pa \cdot l \cdot s^{-1}$(or $Pa \cdot m^3 \cdot s^{-1}$)
q_{cv}	crossover value	Pa·l(or $Pa \cdot m^3$)
q_{pc}	pumping capacity	Pa·l(or $Pa \cdot m^3$)
p_d , p_e	pressures in the test dome for the orifice method	Pa
p_b	base pressure cryogenic vacuum pump	Pa
p_1	vacuum pressure on inlet	Pa
p_2	starting pressure	Pa
D	inner diameter of test dome	m
D_N	nominal diameter of test dome	m
T_{max}	maximum temperature of the second stage	K

5 Test methods

5.1 Test gas

All measurements in this document should be performed with at least 99,9 % (by mass) pure test gas. The test gas should be nitrogen (alternatively dry air), argon and hydrogen.

5.2 Measurement of the volume flow rate (pumping speed)

5.2.1 General

The measurement of volume flow rate is specified in ISO 21360-1.

Pretreatment (see 5.2.4) is recommended before measuring the pumping speed of the test gas (except hydrogen).

When the pressure remains stable within ±3 % (for hydrogen ±5 % is acceptable) for the following minute, the average value per minute can be regarded as valid p_1.

If several test gases are used, without regenerating the pump completely, the gases should be used in the following order: hydrogen, nitrogen (alternatively dry air), argon.

If during measurement more than 30 % of the pumping capacity as indicated by the manufacturer is admitted, the cryogenic vacuum pump should be regenerated.

The test pump should be directly flanged to the test dome (see 5.7.2, Figure 1) or the quick-acting valve (see 5.7.2, Figure 2). The cold surfaces of the test pump shall not protrude into the test dome. Specifically, for cryogenic vacuum pumps with cold surfaces extending beyond the pump inlet flange used in some applications (e.g. semiconductor industry), flanges or pipe adapters should be used to facilitate the connection between the test pump and the test dome to prevent the cold surfaces from protruding into the test dome.

5.2.2 Pretreatment procedure

A quantity of the test gas given by $\alpha \cdot q_{\text{v}}$ is admitted into the cryogenic vacuum pump during the pretreatment. Where, q_{v} is the nominal volume flow rate of the pump and α (α =1 Pa·s) is a proportionality factor determining the quantity of gas to be admitted into. The inlet pressure should be within the measuring pressure range and the operational time should not exceed 60 min.

The pressure shall be measured by the ion gauge, when the pressure change is at least one order below the measured pressure range in which the volume flow rate shall be measured, or if the pressure change satisfies $\frac{\Delta p}{\Delta t} \leq 30 p_1$ (Pa·h^{-1}), the measurement of volume flow rate can be started

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

The throughput method is one of the most widely used methods for vacuum pumps. It is applicable to all pressure ranges and pump sizes where flow meters for gas throughput measurements are available with sufficient accuracy. The type of test dome shall be in accordance with ISO 21360-1: 2020, Figure 1. The complete volume flow rate shall be measured by the throughput method specified in ISO 21360-1:2020, 5.1.

5.2.4 Volume flow rate (pumping speed) measurement by the orifice method

This method is recommended for low gas throughputs where no suitable gas flow meters are available. The complete volume flow rate shall be measured by the orifice method specified in ISO 21360-1:2020, 5.2.

5.2.5 Measurement of water vapour volume flow rate (pumping speed)

Due to the difficulties of obtaining stable water vapour flow and measuring the pressure of the water vapour, the value of water vapour volume flow rate should normally be calculated by Formula (A.1).

5.3 Maximum throughput measurement

5.3.1 General

The maximum throughput is the maximum quantity of gas (Pa·l·s^{-1} or Pa·m^3·s^{-1}), flowing from the test dome through the cryogenic vacuum pump inlet flange, that the pump can withstand while maintaining a given temperature of the second stage. The maximum temperature, T_{max}, depends on the gas species and is set at 20 K for condensable gases (Ar, N_2, O_2 etc.). Therefore, the maximum throughput is the throughput which causes the temperature of the second stage to rise to and remain stable at T_{max}=20 K. The measurement of the maximum throughput is to verify the parameters given by the manufacturer. Therefore, the measurement process is non-destructive and should not be used to obtain the limit value.

5.3.2 Measurement method

The maximum throughput shall be measured using the throughput method specified in 5.2. When the temperature of the second stage reaches 20 K and should remain stable, the measured flow rate is the maximum throughput of the test gas. The recommended test gas is argon.

5.3.3 Measurement setup

For this measurement, the test dome shall be the same as that for the volume flow rate measurement by the throughput method specified in ISO 21360-1:2020, 5.1.2 to 5.1.3. The test dome shall be clean and dry. In addition, the temperature of the second stage shall be measured with a sensor which can measure to an accuracy of ±0,5 K at 20 K.

5.3.4 Measuring procedure

Measuring procedure of the maximum throughput shall be the same as that of the volume flow rate measurement by the throughput method after complete regeneration but without pretreatment. Connect the pump to the test dome, which can establish a constant gas flow and of measuring the pressure, p_1, in the test dome.

The test should be started at least 3 h after the cryogenic vacuum pump completing cooldown. The test gas is admitted into the test dome by the flow meter and the gas inlet valve or mass flow controllers until the temperature of the second stage reaches 20 K ± 3 K and remains stable for 15 min. Record the flow rate, and the temperature. Change the flow, but only sufficiently to stabilize the temperature of the second stage in the range of 17 K to 23 K. In such a manner, record at least six stabilized temperatures and flow rates. The temperature of the first and the second stage shall equilibrate for ≥15 min prior to each reading. Of the six data points, at least two points of the temperature of the second stage measurements shall be taken above 20 K, and at least two points of the temperature of the second stage measurements shall be taken below 20 K. With a minimum of six data points, least squares curve fit a linear relation between throughput and the maximum temperature of the second stage. The maximum throughput is the throughput value at 20 K.

5.4 Pumping capacity measurement

5.4.1 General

Argon and hydrogen are recommended to represent condensable and adsorbable gases, respectively.

5.4.2 Measurement setup

For this measurement, the test dome shall be the same as that for the volume flow rate measurement by the throughput method specified in ISO 21360-1:2020, 5.1.2 to 5.1.3. The test dome shall be clean and dry.

5.4.3 Measuring procedure

A constant throughput of test gas, smaller than the maximum throughput, shall be admitted continuously. Check the throughput and inlet pressure regularly.

In case of argon, the gas flow should be admitted into and interrupted by the recovery method to make sure that the pressure in the test dome still can be reduced to less than 1×10^{-3} Pa in 10 min or less. Also, the inlet pressure shall be less than twice of the initial pressure p_1. If this is not possible, the pumping capacity has been exceeded and the test should be stopped. The cumulative amount of the test gas pumped for each successive measurement shall be calculated.

In case of hydrogen, the gas flow should be admitted into the test dome continuously until the inlet pressure of the test dome increases to twice of the initial pressure p_1. If the pressure in the test dome shall reduce to less than 1×10^{-3} Pa in 10 min or less, calculate the cumulative amount of the test gas pumped during the test period. If this is not possible, the pumping capacity has been exceeded and the test should be stopped and repeated.

The procedure of the recovery method shall be as follows:

a) introduce some constant gas flow for a certain period;

b) stop introducing, and confirm that the pressure decreases below the criteria within a certain period;

c) repeat a) and b).

The test conditions (gas type, flow rate, introduction period, stopping period, and threshold value) shall be specified in the test report.

5.5 Measurement of base pressure cryogenic vacuum pump

The complete measurement of base pressure shall be in accordance with ISO 21360-1:2020, 5.4. However, the pressure shall be measured within 24 h from completing cooldown. This pressure is not the ultimate pressure.

5.6 Measurement of cooldown time

5.6.1 General

The cooldown time is defined as that time elapsed between starting the cryogenic vacuum pump at room temperature at a starting pressure as indicated by the manufacturer and the point at which the temperature of the second stage reaches 20 K. If the cryogenic vacuum pump cannot start at room temperature, report the starting temperature.

NOTE Cooldown time can be affected by ambient humidity.