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Vacuum technology — Standard methods for measuring vacuum pump performance —

Part 3: Specific parameters for mechanical booster vacuum pumps

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

Partie 3: Paramètres spécifiques aux pompes à vide intermédiaires mécaniques

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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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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*.

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 standard methods for measuring the performance characteristics of mechanical booster 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.

The purpose of this document is to ensure that measurements of the performance characteristics of mechanical booster vacuum pumps are, as far as possible, carried out by identical procedures and under identical conditions. As a result, measurements conducted by different manufacturers or in different laboratories, and statements of performance quoted in manufacturers' literature, are intended to be obtained on a properly comparable basis to the benefit of both user and manufacturer.

Vacuum technology — Standard methods for measuring vacuum pump performance —

Part 3: Specific parameters for mechanical booster vacuum pumps

1 Scope

This document specifies methods and special requirements for measuring the maximum tolerable pressure difference, effective compression ratio, compression ratio with zero throughput and overflow valve pressure difference of mechanical booster vacuum pumps.

It applies to mechanical booster vacuum pumps employed for medium vacuum or rough vacuum applications including gas-cooled mechanical booster vacuum pump and multiple mechanical booster vacuum pump systems.

It covers particular characteristics of mechanical boosters that are different from those of the usual positive displacement vacuum pumps. Maximum tolerable pressure difference Δp_{max}, effective compression ratio K_{eff}, compression ratio with zero throughput K_0 and overflow valve pressure difference Δp_1 are special characteristics of the performance of mechanical booster vacuum 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 3529-1, *Vacuum technology — Vocabulary — Part 1: General terms*

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

ISO 3567, *Vacuum gauges — Calibration by direct comparison with a reference gauge*

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 3529-1 and 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
mechanical booster vacuum pump
vacuum pump based on mechanical principles used between the backing pump and the high vacuum pump or process chamber to increase the throughput of the pumping system in medium vacuum or rough vacuum application, or to improve the compression within the system and so reduce the volume flow rate needed for the backing pump

Note 1 to entry: Several mechanical booster vacuum pumps may be cascaded for higher performance.

Note 2 to entry: In some applications, mechanical booster vacuum pumps are used for gas recirculation as well.

[SOURCE: ISO 3529-2:1981, 2.4.6, modified — The expressions "based on mechanical principles" and "or process chamber" have been added, "a medium range of pressure" has been replaced by "medium vacuum or rough vacuum application", " the pressure stages" has been replaced by "the compression".]

3.2
overflow valve pressure difference
Δp_1
pressure difference between the backing pressure p_3 and the inlet pressure p_1 immediately before the valve opens

3.3
maximum tolerable pressure difference
Δp_{max}
maximum pressure difference between the backing pressure p_3 and the inlet pressure p_1 that the test pump is able to withstand under continuous operation without any deterioration or damage

$$\Delta p_{max} = p_3 - p_1 \tag{1}$$

3.4
effective compression ratio
K_{eff}
ratio of the backing pressure p_3 to the inlet pressure p_1 of the mechanical booster vacuum pump

$$K_{eff} = \frac{p_3}{p_1} \tag{2}$$

4 Symbols

Symbol	Designation	Unit
D	inner diameter of test dome	m
D_N	nominal diameter of test dome	m
p_1	vacuum pressure on inlet	Pa (or mbar)
p_3	vacuum pressure in backing line	Pa (or mbar)
Δp_{max}	maximum tolerable pressure difference of test pump	Pa (or mbar)
K_0	compression ratio of test pump with zero throughput	—
$K_{0,max}$	maximum compression ratio of test pump with zero throughput	—
K_{eff}	effective compression ratio	—

Δp_1	overflow valve pressure difference of test pump	Pa (or mbar)
p_b	base pressure	Pa (or mbar)
u	measurement uncertainty	—

5 Measurement conditions

a) Environmental conditions shall be in accordance with ISO 21360-1.

b) Measurements are made with dry gas. Generally, test gas or air with relative humidity 65 % or below.

c) The backing pump shall provide an appropriate backing pressure and operate within normal working parameters during the measurement period.

d) There shall be no liquid in the pump housing of test pump, no medium other than the test gas shall be admitted in the housing.

e) Where cooling water is required, it shall be provided in accordance with manufacturer's specifications.

f) Rotational speed of the motor and the frequency controller system shall be in accordance with manufacturer's specifications. The rotational speed of the motor shall be within ± 3 % of the rated rotational speed.

g) It is recommended that all measurements be made with the same gas. Where different gases are used, the apparatus shall be purged with the new gas before measurement begins. In addition, it is preferable to use a gas independent vacuum gauge or a gauge calibrated for the test gases. A corresponding calibration table shall be provided for each gas species.

h) The leak rate of the experimental setup shall be less than 10^{-4} Pa·m^3/s. This shall be measured immediately before or immediately after the test.

6 Experimental setup

6.1 General

The test domes shall be clean and dry. The cleanness of the pump, seals and other components shall be appropriate for the expected base pressure. All components shall be assembled as shown in Figure 1 under clean conditions and in accordance with the manufacturer's instructions.

All measuring devices shall be calibrated either

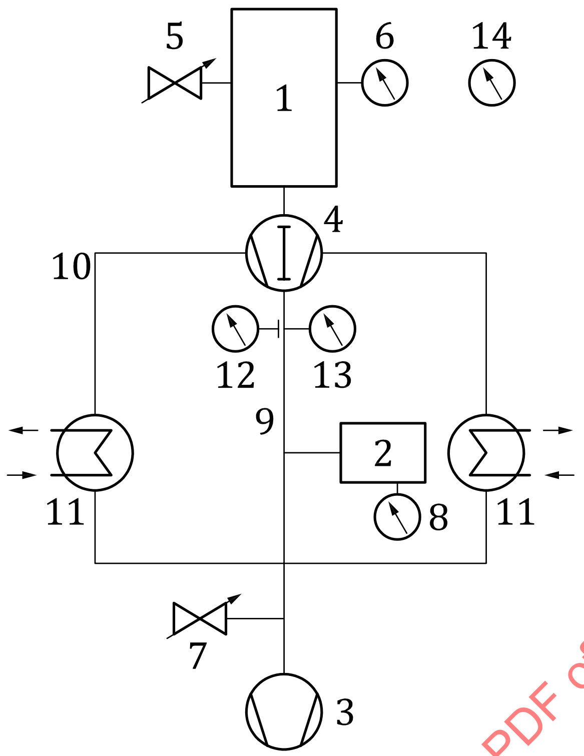
a) in a traceable way to a vacuum primary or national standard, or

b) by means of instruments of absolute measure which are traceable.

The pressure measurements are performed with total pressure vacuum gauges, which shall be calibrated as specified in ISO 3567, or by means of instruments which are traceable to SI units. In the case of calibrated measuring instruments, there should exist a calibration certificate in accordance with ISO/IEC 17025[3].

6.2 Schematic diagram

The schematic diagram of experimental setup is shown in Figure 1.



Key

1 test dome on test pump
2 buffer volume on backing line
3 backing pump
4 test pump
5 adjustable gas inlet valve A
6 vacuum gauge to measure p_1
7 adjustable gas inlet valve B
8 vacuum gauge to measure p_3
9 backing line
10 returning cooled-gas line (for gas-cooled mechanical booster vacuum pump only)
11 cooler (for gas-cooled mechanical booster vacuum pump only)
12 thermometer to measure housing temperature at outlet flange
13 thermometer to measure gas temperature at outlet
14 thermometer to measure ambient temperature

NOTE 1 The returning cooled gas line and cooler are required only if the test pump is a gas-cooled mechanical booster pump. For guidance on the design and manufacture of the measuring equipment, see Figure B.2.

NOTE 2 Adjustable gas inlet valve A (5) is not required to measure the compression ratio with zero throughput and overflow valve pressure difference.

Figure 1 — Experimental setup

For test pumps which exhaust the gas against atmospheric pressure, there is no backing pump (3) and the measurement of p_3 is replaced with a measurement of the ambient atmospheric pressure.

For gas-cooled mechanical booster pumps which exhaust the gas against atmospheric pressure, the cooling gas port should be opened to admit ambient air during measurement.

6.3 Test dome on test pump

A suitable test dome and adapter, as specified in ISO 21360-1:2012, 5.1.2, shall be selected. Recommendations for the inner diameter are given in Table A.1. For test 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 conical adapter to the pump inlet flange shall be selected in accordance with Annex A.

6.4 Buffer volume on backing line

To reduce pressure fluctuations, the combined volume of the buffer volume (2) and the backing line (9) shall be a minimum of five times the swept volume of the mechanical booster vacuum pump (see ISO 21360-2:2012, 5.1.2)

A buffer volume (2) is not required when the backing line volume meets this requirement. Where a buffer volume is necessary, it shall be sized accordingly with a minimum diameter equal to or greater than that of the backing line.

6.5 Vacuum gauges

The installation orientation of the vacuum gauges (vertical, horizontal or inclined) shall match the orientation of the gauge when calibrated to minimize the impact measurement uncertainty.

Where measurements are performed with different gas species, a gas independent vacuum gauge or a gauge calibrated for the test gases shall be used.

7 Test methods

7.1 Measurement of maximum tolerable pressure difference, Δp_{max}

7.1.1 General

If the test pump is fitted with an overflow valve, this shall be locked closed during the test.

7.1.2 Measuring method

Test gas is admitted to the test dome and backing line until the desired inlet pressure and pressure difference between the inlet and backing line is reached. The test pump shall be operated until the body temperature and outlet gas temperature are stable. It is recommended that the inlet pressure is equal to or less than 1×10^3 Pa.

For any given inlet pressure, the maximum difference between the backing pressure, p_3, and the inlet pressure, p_1, when the test pump operates continuously without any failure and within the technical specifications, e.g. the maximum oil or bearing temperature, is the maximum tolerable pressure difference, Δp_{max}.

7.1.3 Measuring procedure

The arrangement of the experimental setup is given in Figure 1. Gas is admitted to the test dome by simultaneously adjusting gas inlet valve A (5) and gas inlet valve B (7) on the backing line. The backing pressure, p_3, and the inlet pressure, p_1, shall be measured simultaneously. If the test pump operates for 1 h without any failure after thermal stabilization, the maximum difference between them will be the maximum tolerable pressure difference, Δp_{max}.

NOTE Measurements can be performed with different gas species. When the gas for test is changed, all pipes connected to the gas inlet valve are purged with the new gas before the beginning of the measurement.

7.1.4 Measurement uncertainty

The pressure should be measured with an uncertainty of less than ± 3 %. The total uncertainty of the maximum tolerable pressure difference shall be less than 10 %.

NOTE For the calculations, see Annex C.

7.1.5 Evaluation of the measurement

The maximum tolerable pressure difference, Δp_{max}, is calculated using Formula (1).

7.1.6 Test report

The test report should contain all data described in 8.2 to 8.4 and additionally the measurement of maximum tolerable pressure difference, Δp_{max}:

n) maximum tolerable pressure difference $\Delta p_{max} = p_3 - p_1$.

7.2 Measurement report of compression ratio K_0

7.2.1 General

Measure the compression ratio, K_0, in accordance with ISO 21360-1:2012, 5.5.2. The arrangement of the experimental setup is shown in Figure 1.

7.2.2 Test report

The test report should contain all data described in 8.2 to 8.4 and the following additional data:

n) compression ratio $K_0 = p_3/p_1$;

o) fluids (if used) and vapour pressures at 20 °C used in the test pump;

p) type of coolers if employed in the test and their temperatures, base pressure of the backing pump and test pump.

7.3 Measurement of the effective compression ratio K_{eff}

7.3.1 Backing pump selection

The backing pump capacity shall be adequate to achieve the desired outlet pressure of the mechanical booster vacuum pump with the anticipated flow.

The complete K_{eff} measurement by throughput method is similar to ISO 21360-1:2012, 5.1. The arrangement of the experimental setup is shown in Figure 1 with the additional requirements of the outlet pressure of the mechanical booster vacuum pump controlled by using valve B (Figure 1, key item 7), by varying the frequency of the backing pump or using an adjustable conductance valve (as in ISO 21360-1:2012, Figure 8, key item 9) or a combination of these methods.

7.3.2 Test report

The test report shall contain all data described in 8.2 to 8.4 and the following additional data:

n) the compression ratio K_{eff} versus throughput or volume flow rate of the test pump;

o) fluids (if used) and vapour pressures at 20 °C used in the test pump;

p) type of coolers if employed in the test and their temperatures, base pressure of backing pump and test pump.

7.4 Measurement of overflow valve pressure difference Δp_1

7.4.1 General

This covers the measurement of the pressure difference when the overflow valve opens.

Ensure that the valve functions reliably and consistently prior to test.

7.4.2 Determination of overflow valve pressure difference

The overflow valve pressure difference, Δp_1, is defined according to Formula (3):

$$\Delta p_1 = p_3 - p_1 \tag{3}$$

7.4.3 Measuring method

With the gas inlet valve of the test pump closed, increase the pressure in the backing line until the overflow valve opens.

7.4.4 Measuring procedure

The arrangement of the experimental setup is given in Figure 1.

Close the test pump gas inlet valves. Allow the test pump to reach a stable operational temperature.

Slowly admit dry gas to the backing line by adjusting gas inlet valve B (7). The difference between the backing pressure, p_3, and inlet pressure, p_1, when the overflow valve opens is the overflow valve pressure difference, Δp_1.

7.4.5 Overflow valve opening

When the difference between backing pressure, p_3, and inlet pressure, p_1, exceeds the overflow valve pressure difference, Δp_1, the valve will open. This is indicated by the sudden increase in inlet pressure, p_1.

7.4.6 Measurement uncertainty

The pressure should be measured with an uncertainty of less than ± 3 %. The total uncertainty of the overflow valve pressure difference shall be < 10 %.

NOTE For the exact calculation, see Annex C.

7.4.7 Evaluation of the measurement

At least five measurements shall be taken. The overflow valve pressure difference, Δp_1, shall be the average of measured values. The inlet pressure, p_1, backing pressure, p_3, and overflow valve pressure difference, Δp_1, shall be recorded.

7.4.8 Test report

The test report shall contain all data described in 8.2 to 8.4 and the following additional data:

n) the overflow valve pressure difference Δp_1.

8 Test report

8.1 Content

The test report should contain the following general data on the pump parameters (see 8.2), the test equipment and conditions (see 8.3) and the operational parameters (see 8.4). Additional data specific to the type of test are described in 7.1.6, 7.2.2, 7.3.2 and 7.4.8.

8.2 Report on pump parameters

The test report shall contain the following general information about the tested pump:

a) the type and the article/serial number of the mechanical booster vacuum pump;

b) the flange type and size of the mechanical booster vacuum pump;

c) the type and the article/serial number of the driving unit (motor, frequency controller) if not fixed part of the test pump;

d) the nominal rotational speed, min./max. rotational speed and maximum power consumption of the mechanical booster vacuum pump.

8.3 Report on test equipment and conditions

The test report shall contain the following general information about the test equipment and conditions:

e) the type and operational conditions of vacuum gauges used;

f) the type of seals used upstream from the inlet flange of the test pump;

g) D_N (size of the test dome and flange type);

h) the flow rate and temperature of cooling water;

i) ambient temperature and atmosphere pressure;

j) type, serial number and nominal pumping speed of the backing pump.

8.4 Report on operational parameters

All measurement reports shall contain the following items:

k) the inlet pressure, p_1, and the backing pressure, p_3, of test pump;

l) the gas temperature at outlet, the housing temperature at outlet flange;

m) test gas species.

Annex A
(normative)

Test dome

As shown in Figure 1, a test dome is required for the experimental setup.

Test domes and conical adaptors are described in ISO 21360-1:2012, 5.1.2.

The length of adaptor shall be not more than 0,5 D.

The volume of the test dome, V_D, shall be at least five times the swept volume during one compression cycle V_P when V_P is less than 65 l and the volume of the test dome V_D shall be set to 1 300 l when the swept volume, V_P, is more than 65 l. The appropriate test dome for different swept volume V_P is indicated in Table A.1.

For pumps where the calculated inner diameter of test dome shall be less than D_N = 100 mm, the diameter of fitted dome shall correspond to D_N = 100 mm.

A swept volume is the ratio of the nominal pumping speed to the nominal rotational speed, they shall adopt the same unit.

Table A.1 — Test dome specifications

V_P l	V_D l	D mm
0~0,26	1,3	100
0,26~1,1	5,4	160
1,1~4,2	21	250
4,2~17	84	400
17~65	325	630
> 65	1 300	1 000

Key

V_P: swept volume

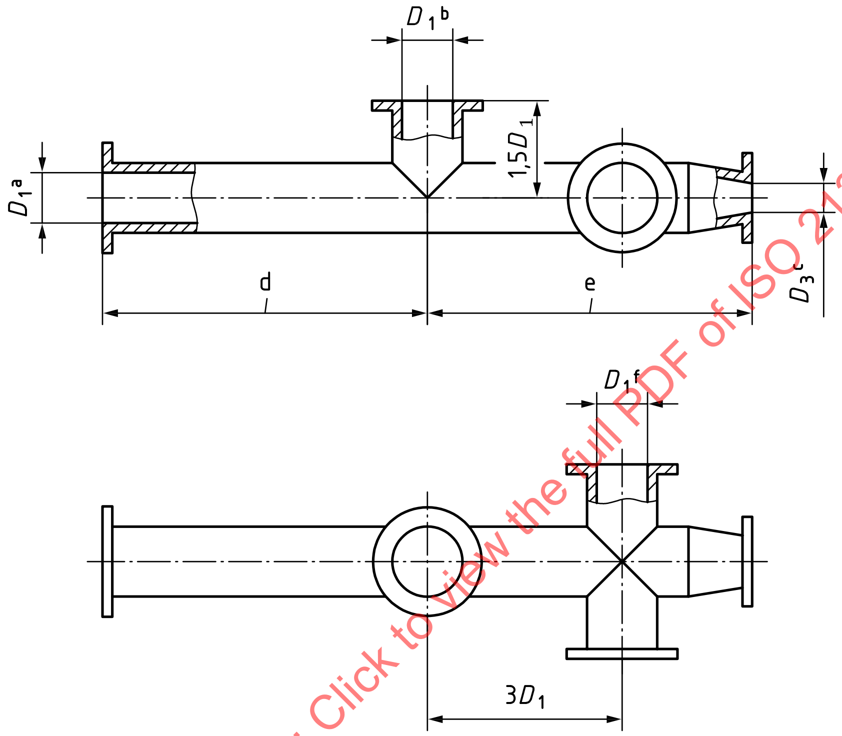
V_D: volume of the test dome

D: inner diameter of test dome

Annex B
(informative)

Backing line and returning cooled-gas line

The dimension of backing line is shown in Figure B.1.



a Nominal diameter of the outlet of mechanical booster vacuum pumps.

b Connection to buffer volume on backing line.

c Nominal diameter of the inlet of backing pump.

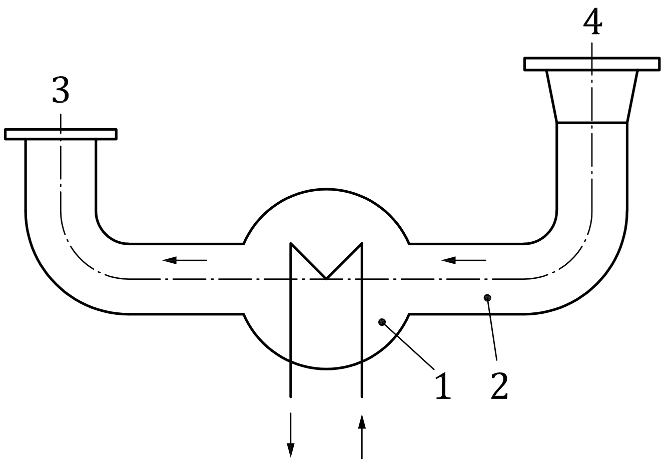
f Connection to returning cooled-gas pipe or closed.

"c" shall include the equivalent length of any elbow used to attach the backing line to the test pump

NOTE d = e.

Figure B.1 — Backing line basic dimensions

Where the pump under test is gas cooled the returning cooled-gas pipe shall be sized adequate for the function of the mechanical booster vacuum pump in accordance with the manufacturer's instructions. It has no significant effect on measurement.



Key

1 cooler

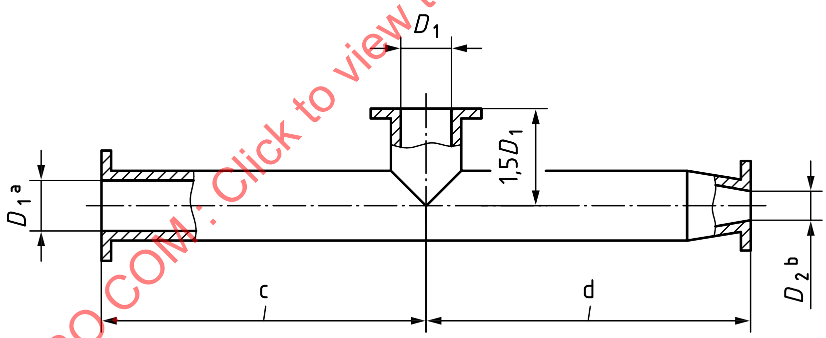
2 returning cooled-gas pipe

3 connection to returning cooled-gas port of test pump

4 connection to backing line

Figure B.2 — Returning cooled-gas line

The backing line as shown in Figure B.1 can be simplified as shown in Figure B.3. This design is not suitable for measurements on gas-cooled mechanical booster pump.



a Nominal diameter of the outlet of mechanical booster vacuum pumps

b Nominal diameter of the inlet of backing pumps

"c" shall include the equivalent length of any elbow used to attach the backing line to the test pump

NOTE c = d.

Figure B.3 — Simplified backing line basic dimensions