BS ISO 21360-2:2012

BSI Standards Publication

Vacuum technology — Standard methods for measuring vacuum-pump performance

Part 2: Positive displacement vacuum pumps

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National foreword

This British Standard is the UK implementation of ISO 21360-2:2012.

The UK participation in its preparation was entrusted to Technical Committee MCE/8/-/4, Vacuum technology.

A list of organizations represented on this committee can be obtained on request to its secretary.

ISBN 978 0 580 61681 5

ICS 23.160

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2012.

Amendments issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 21360-2

First edition
2012-04-15

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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Published in Switzerland

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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.

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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
$p_{\mathrm{H_2O}}$
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, $P_{0\mathrm{B}}$, 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, $P_{0\mathrm{B}}$, 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.

Annex A
(informative)

Measurement of the water vapour tolerance

A.1 Measurement of the water vapour tolerance

A.1.1 General

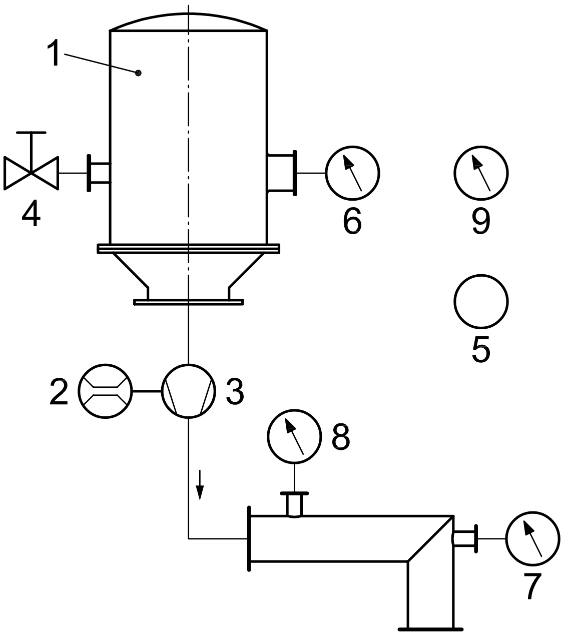
If vapour, especially water vapour, is conveyed by a vacuum pump, it can condense in the pump before the exhaust valve opens against the atmospheric pressure. Condensed liquids mix with the pump oil and re-evaporate in the suction range of the pump. This leads to higher base pressures and possibly to corrosion in the pump. To avoid condensation, admit air or another non-condensable gas to the pump through a special gas-ballast duct, which may be closed with a valve.

Pumping of water vapour can raise power consumption and temperature with some types of pump, which leads to a higher saturation vapour pressure which supports a higher water vapour tolerance.

Using water vapour for measurement is a direct method, but one which can lead to unnoticed condensation in the pump. Therefore, in this part of ISO 21360 for oil-sealed pumps, a method is specified using dry air instead of water vapour. The temperature rise of the pump, caused by an equivalent air throughput, is used to determine the water vapour saturation temperature. The temperature of the exhaust gases is measured, dependent on the inlet pressure, p_1. Because of the different compression powers for triatomic water and diatomic air molecules, it is necessary to correct for the temperature rise caused by air.

A.1.2 Experimental setup

See Figures A.1 and A.2.



Key

1 test dome (referred to in the throughput-test type configuration, ISO 21360-1:2012, 5.1.2)

2 flow meter [measures gas ballast throughput $B_{(p_\mathrm{B}+p_\mathrm{a})}$]

3 test pump

4 gas inlet valve

5 hygrometer (measures relative humidity, $\varphi_{\mathrm{H_2O}}$)

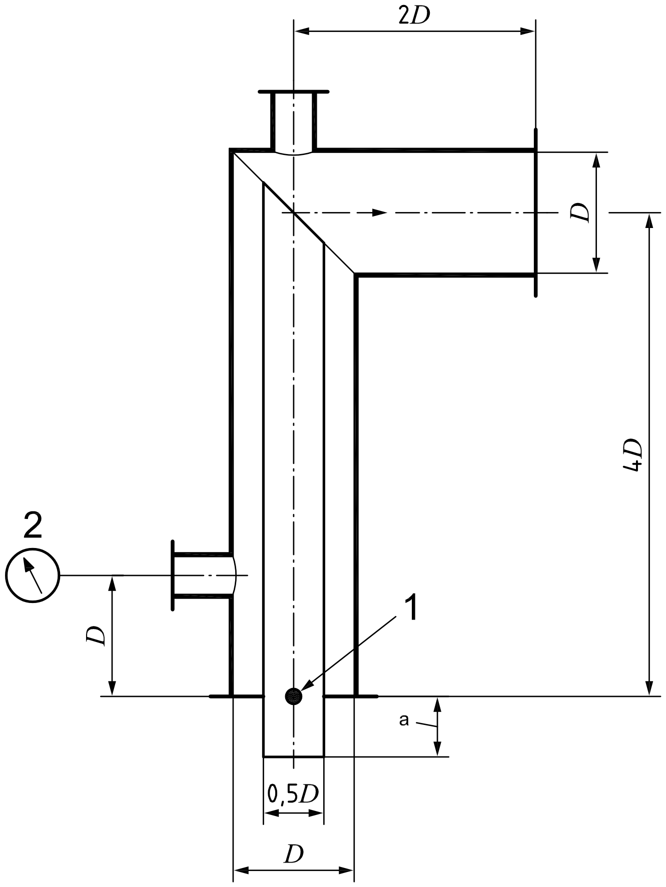
6 vacuum gauge (measures inlet pressure, p_1)

7 thermometer to measure exhaust pressure temperature

8 pressure gauge for exhaust pressure

9 pressure gauge for atmospheric pressure

Figure A.1 — Arrangement for the measurement of water vapour tolerance



Key

1 temperature measuring point for T_2
2 pressure gauge for exhaust pressure
D inner diameter of the pipe
[a] 0 to 0,5D.

Figure A.2 — Pipe elbow for measuring pump temperature and exhaust pressure (example)

A.1.3 Determination of the water vapour tolerance

The equation for the water vapour tolerance is:

$$p_{\mathrm{H_2O}} = \frac{q_{V\mathrm{B}} p_\mathrm{B}}{q_V} \frac{p_\mathrm{s}\left[1+\left(p_\mathrm{a} / p_\mathrm{B}\right)\right]-\left(\alpha p_0 / p_\mathrm{B}\right) p_\mathrm{a}}{\alpha p_0 - p_\mathrm{s}} \quad \text{(A.1)}$$

Setting the factors 1 + ($p_\mathrm{a}/p_\mathrm{B}$) and $\alpha p_0/p_\mathrm{B}$ to a value of 1 results in the commonly used Equation (A.2):

$$p_{\mathrm{H_2O}} = \frac{q_{V\mathrm{B}} p_\mathrm{B}}{q_V} \frac{p_\mathrm{s} - p_\mathrm{a}}{\alpha p_0 - p_\mathrm{s}} \quad \text{(A.2)}$$

For better accuracy, Equation (A.1) is used in the following.

The values of $q_{V\mathrm{B}}$, q_V, α, p_0, p_B and p_a can be measured directly, but not that of the water vapour saturation pressure, p_s. Because air is used instead of water vapour, the exhaust temperature, T_2, is measured as a function of different inlet pressures, p_1. During compression in the pump, no heat exchange with the environment occurs. That means that the compression is adiabatic. Because of the different adiabatic exponents, κ, for air and water vapour, there are different consumptions of compression power. The compression energy is given by Equation (A.3) (Reference [1], p. 249):

$$W_{\mathrm{ad}} = \frac{\kappa}{\kappa - 1} p_1 V_{\mathrm{s}} \left[\left(\frac{\alpha p_0}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right] \tag{A.3}$$

The temperature rise of the pump is proportional to the compression power consumption and is different for air and water vapour. As a result, the measured pump temperature, T_2, has to be corrected by the ratio $W_{\mathrm{ad,\,H_2O}} / W_{\mathrm{ada}}$.

The relation between the saturation vapour pressure, p_{s}, and its associated temperature, $T_{2\mathrm{s}}$, is described by the vapour pressure Equation (A.4):

$$\ln \frac{p_{\mathrm{s}}}{p_{T_0}} = -\frac{L}{R} \left(\frac{1}{T_{2\mathrm{s}}} - \frac{1}{T_0} \right) \tag{A.4}$$

where

L is the evaporation energy;

R is the general gas constant;

T_0, p_{T_0} are two values from the water vapour equation, see Annex C (e.g. T_0 = 323 K and $p_{T_0} = 12{,}24$ kPa).

The value of T_0 should be chosen to be near the temperature range of the pump.

In Equation (A.1), $p_{\mathrm{H_2O}}$ can be substituted by the inlet pressure, p_1:

$$p_1 = \frac{q_{V\mathrm{B}} p_{\mathrm{B}}}{q_V} \frac{p_{\mathrm{s}} \left[1 + \left(p_{\mathrm{a}} / p_{\mathrm{B}} \right) \right] - \left(\alpha p_0 / p_{\mathrm{B}} \right) p_{\mathrm{a}}}{\alpha p_0 - p_{\mathrm{s}}} \tag{A.5}$$

Rearranging Equation (A.5) to give p_{s} yields:

$$p_{\mathrm{s}} = \alpha p_0 - \frac{\alpha p_0}{\left(p_1 q_V / p_{\mathrm{B}} q_{V\mathrm{B}} \right) + \left(p_{\mathrm{a}} / p_{\mathrm{B}} \right) + 1} \tag{A.6}$$

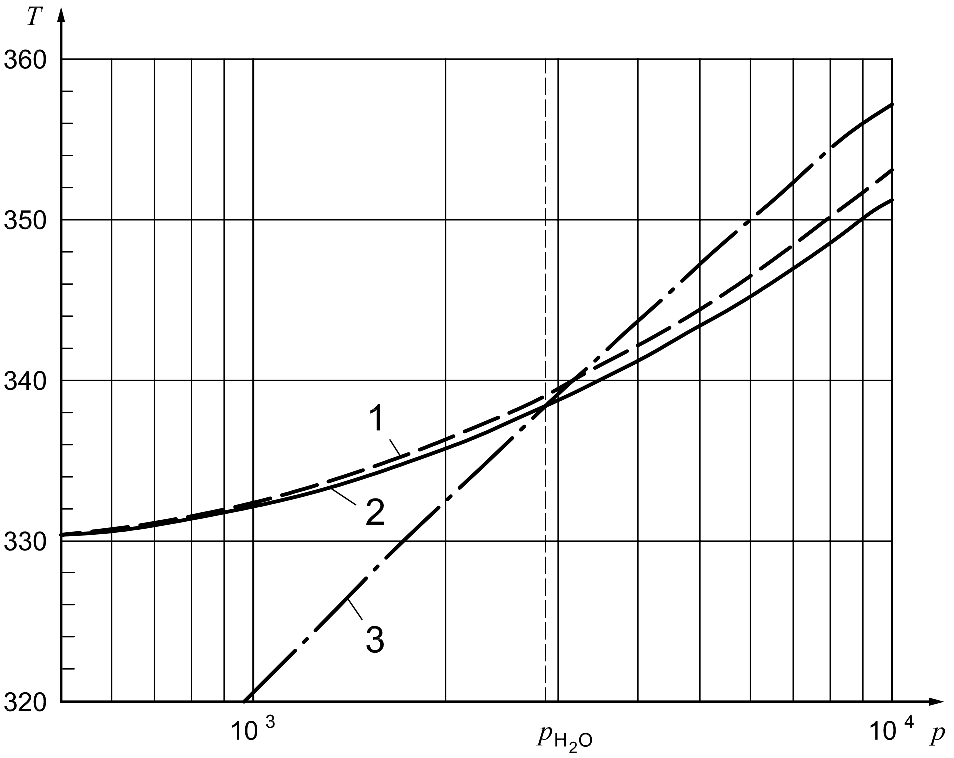
Rearranging Equation (A.4) to give $T_{2\mathrm{s}}$ yields:

$$T_{2\mathrm{s}} = 1 \Bigg/ \left[\frac{1}{T_0} - \frac{R}{L} \ln \frac{p_{\mathrm{s}}}{p_{T_0}} \right] \tag{A.7}$$

indicating the relationship between inlet pressure, p_1, and the saturation temperature, $T_{2\mathrm{s}}$. Thus a calculated exhaust saturation temperature curve as a function of the inlet pressure can be generated.

IMPORTANT Equation (A.7) is only valid for constant evaporation energy over the temperature range used.

At this juncture, both curves, the measured pump temperature curve, $T_2(p_1)$, and the calculated saturation temperature curve, $T_{2\mathrm{s}}(p_1)$, can be plotted on a graph (see Figure A.3).



Key

1	exhaust pump temperature, T_2
2	corrected exhaust pump temperature, T_{2cr}
3	exhaust saturation temperature, T_{2s}
T	exhaust temperature
p	water vapour saturation pressure
p_{H_2O}	water vapour tolerance value

Figure A.3 — Exhaust temperature and water vapour saturation temperature vs inlet pressure (example)

A.1.4 Measuring procedure

At different air throughputs, operate the pump with the gas ballast valve open for a period of time until the pump temperature has stabilized. Higher inlet pressures generate higher pump temperatures. The gas throughputs shall be chosen so that the inlet pressures are of the order of the expected water vapour tolerance, p_{H_2O} .

The experimental setup is shown in Figure A.1. First operate the pump with the gas inlet valve closed and the gas ballast valve open until the temperature rise over a period of 15 min is <0,5 K. Then measure the exhaust temperature, T_{20}, and the gas ballast throughput, $q_{VB}(p_B + p_a)$, and maintain them at constant values during all subsequent measurements. Next, admit dry air to the pump inlet, adjust the first inlet pressure, p_1, with the input valve, and measure the equilibrium temperature of the exhaust gas, T_2. Repeat this step for a minimum of four different inlet pressures. At least one of the inlet pressures should be higher than the expected water vapour tolerance.

Subsequently, measure the following values: the environmental temperature, T_1, which should be within the limits described in ISO 21360-1; the atmospheric pressure, p_0; the relative humidity, φ_{H_2O} , of the environmental atmosphere, expressed as a percentage.

The volume flow rate of the pump, q_V, should have been measured previously (see Clause 5). The measurements may only be started if the atmospheric pressure, p_0, is <107 kPa. The pressure difference between the exhaust pressure, p_2, and the atmospheric pressure shall be ±1 kPa.

A.1.5 Evaluation of the measurements

The measured temperature values, T_2, have to be reduced by the ratio of the adiabatic compression energies [given by Equation (A.3)] of water vapour, $W_{\mathrm{ad,\,H_2O}}$ with $\kappa = 1{,}333\,3$, and of air, W_{ada}, with $\kappa = 1{,}4$. The correction factor, W_{cr}, is given by

$$W_{\mathrm{cr}} = \frac{W_{\mathrm{ad,\,H_2O}}}{W_{\mathrm{ada}}} \tag{A.8}$$

Values for W_{cr} are listed in Table A.1.

Table A.1 — Values for W_{cr}

p_0/p_1	$W_{\mathrm{cr}} = W_{\mathrm{ad,\,H_2O}} / W_{\mathrm{ada}}$
1 000	0,849 7
200	0,887 5
100	0,903 4
50	0,918 9
20	0,938 9
10	0,953 5

T_{20} is subtracted from the values of T_2 associated with the inlet pressures, p_1, and the difference, $T_2 - T_{20}$, is multiplied by W_{cr}. The corrected temperature difference is then added again to T_{20}:

$$T_{2\mathrm{cr}} = W_{\mathrm{cr}}\,(T_2 - T_{20}) + T_{20} \tag{A.9}$$

$T_{2\mathrm{cr}}$ is the corrected pump exhaust temperature for water vapour and is plotted against p_1 in a graph such as Figure A.3.

To obtain the exhaust saturation temperature curve, $T_{2\mathrm{s}}(p_1)$, insert the measured values of p_1, $q_{V\mathrm{B}}$, and p_0 into Equation (A.6) to get, as the first step, the saturation pressure, p_s.

The atmospheric pressure due to water vapour content, p_a, can be obtained from

$$p_0 = p_\mathrm{B} + p_\mathrm{a}$$

Measure the relative humidity, $\varphi_{\mathrm{H_2O}}$, as a percentage of the saturation water vapour pressure. The water vapour partial pressure is:

$$p_\mathrm{a} = \frac{\varphi_{\mathrm{H_2O}}}{100\,p_\mathrm{s}\left(T_1\right)}$$

Table C.1 lists values of $p_\mathrm{s}(T_1)$. Hence follows: $p_\mathrm{B} = p_0 - p_\mathrm{a}$. The factor α can be set to around 1,1. With these values, calculate p_s with Equation (A.6) for all inlet pressures p_1.

Then, in a second step, calculate the exhaust saturation temperatures $T_{2\mathrm{s}}$ using Equation (A.7), inserting the saturation pressures, p_s, from Equation (A.6). Set T_0 to 323 K; the corresponding saturation pressure, p_{T_0}, is 12,34 kPa. In the important temperature range 50 °C to 100 °C, the molar evaporation energy, L, is 41 922 J/mol and the general gas constant, R, is 8,314 3 J/(K·mol).

Plot the exhaust saturation temperatures thus calculated against the inlet pressure, p_1, on a graph, such as Figure A.3. The abscissa of the intersection point of these two curves is the water vapour tolerance, $p_{\mathrm{H_2O}}$.

A.1.6 Measuring uncertainties

The following values can influence the accuracy of the water vapour tolerance, p_{H_2O} :

a) environmental temperature, T_1;

b) atmospheric pressure, p_0;

c) pressure-increasing factor to open the exhaust valve, α;

d) molar evaporation energy, L;

e) water content of air used for inlet into the test dome;

f) exhaust pump temperature, T_2;

g) corrected exhaust temperature, T_{2cr};

and all other values used in the above-mentioned formulae.

Annex B
(informative)

Calculation of the water vapour tolerance

For inlet of pure-water vapour for one pump cycle, a good approximation is obtained from the ideal gas law:

$$\frac{p_B V_B}{T_2} + \frac{p_a V_B}{T_2} + \frac{p_{H_2O} V_{SW}}{T_2} = \frac{\alpha p_0 V_2}{T_2} \tag{B.1}$$

The Boyle–Mariotte law for the gas ballast air part is:

$$p_B V_B = p_2 V_2$$

Hence it follows that:

$$V_2 = \frac{p_B V_B}{p_2}$$

The opening pressure of the exhaust valve is:

$$\alpha p_0 = p_2 + p_s(T_2) \tag{B.2}$$

Putting in p_2 and V_2 results in:

$$p_B V_B + p_a V_B + p_{H_2O} V_{SW} = \frac{\alpha p_0 p_B V_B}{\alpha p_0 - p_s(T_2)} = p_B V_B \Big/ \left[1 - \frac{p_s(T_2)}{\alpha p_0} \right] \tag{B.3}$$

Hence it follows that

$$p_{H_2O} = \frac{V_B}{V_{SW}} \left[\frac{p_B}{1 - (p_s / \alpha p_0)} - p_B - p_a \right] \tag{B.4}$$

or

$$p_{H_2O} = \frac{V_B}{V_{SW}} \frac{p_B \left\{ p_s \left[1 + (p_a / p_B) \right] - (\alpha p_0 p_a / p_B) \right\}}{\alpha p_0 - p_s} \tag{B.5}$$

The formula for the water vapour tolerance is (Reference [1], p. 247):

$$p_{H_2O} = \frac{V_B}{V_{SW}} \frac{p_B (p_s - p_a)}{\alpha p_0 - p_s} \tag{B.6}$$

Equation (B.5) contains factors $1 + (p_a/p_B)$, which is nearly 1, and $\alpha p_0 / p_B > 1{,}1$, whereas Equation (B.6) does not. Both factors should be considered, because no further measuring values are necessary.

Annex C
(informative)

Table of the saturation vapour pressure of water

Table C.1 — Table of the saturation vapour pressure of water

T_0 K	p_{T_0} Pa	T_0 K	p_{T_0} Pa
273	603,6	313	7 314,5
274	649,1	314	7 714,0
275	697,5	315	8 132,1
276	749,1	316	8 569,7
277	804,0	317	9 027,4
278	862,4	318	9 506,0
279	924,6	319	10 006,3
280	990,7	320	10 529,0
281	1 060,9	321	11 075,1
282	1 135,4	322	11 645,3
283	1 214,6	323	12 240,6
284	1 298,5	324	12 861,8
285	1 387,5	325	13 509,7
286	1 481,8	326	14 185,5
287	1 581,7	327	14 889,9
288	1 687,5	328	15 624,1
289	1 799,4	329	16 389,0
290	1 917,7	330	17 185,6
291	2 042,9	331	18 015,0
292	2 175,1	332	18 878,4
293	2 314,8	333	19 776,8
294	2 462,2	334	20 711,4
295	2 617,8	335	21 683,3
296	2 782,0	336	22 693,6
297	2 955,0	337	23 743,8
298	3 137,4	338	24 834,9
299	3 329,5	339	25 968,2
300	3 531,8	340	27 145,1
301	3 744,7	341	28 367,0
302	3 968,7	342	29 635,1
303	4 204,3	343	30 950,9
304	4 452,0	344	32 315,7
305	4 712,3	345	33 731,1
306	4 985,6	346	35 198,5
307	5 272,7	347	36 719,3
308	5 573,9	348	38 295,2

Table C.1 *(continued)*

T_0 K	p_{T_0} Pa	T_0 K	p_{T_0} Pa
309	5 889,9	349	39 927,8
310	6 221,4	350	41 618,6
311	6 568,9	351	43 369,2
312	6 933,0	352	45 181,4

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ICS 23.160

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