



Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3



AS ISO 9906:2018

This Australian Standard ® was prepared by ME-030, Pumps. It was approved on behalf of the Council of Standards Australia on 16 January 2018.

This Standard was published on 22 February 2018.

The following are represented on Committee ME-030:

- Australasian Fire and Emergency Service Authorities Council
- Engineers Australia
- Fire Protection Association Australia
- Irrigation Australia
- Master Plumbers Australia
- Pump Industry Australia
- Water Services Association of Australia

This Standard was issued in draft form for comment as DR AS ISO 9906:2017.

Keeping Standards up-to-date

Ensure you have the latest versions of our publications and keep up-to-date about Amendments, Rulings, Withdrawals, and new projects by visiting:

www.standards.org.au

www.saiglobal.com (sales and distribution)

ISBN 978 1 76035 999 7



Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3

Originated as AS CB9—1931.
Previous editions AS 2417.1—1980, AS 2417.2—1980 and AS 2417.3—1980.
AS 2417.1—1980, AS 2417.2—1980 and AS 2417.3—1980 revised, amalgamated and
redesignated as AS 2417—2001.
Revised and redesignated as AS ISO 9906:2018.

COPYRIGHT

© ISO 2018 — All rights reserved
© Standards Australia Limited 2018

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968 (Cth).

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia.

Preface

This Standard was prepared by the Standards Australia Committee ME-030, Pumps, to supersede AS 2417—2001, *Rotodynamic pumps—Hydraulic performance acceptance tests—Grades 1 and 2*.

The objective of this Standard is to specify hydraulic performance tests for customers' acceptance of rotodynamic pumps (centrifugal, mixed flow and axial pumps). It is intended to be used for pump acceptance testing at pump test facilities, such as manufacturers' pump test facilities or laboratories.

This Standard is identical with, and has been reproduced from, ISO 9906:2012, *Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3*.

As this document has been reproduced from an International Standard, the following applies:

- (a) In the source text 'this International Standard' should read 'this Australian Standard'.
- (b) A full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms 'normative' and 'informative' are used in Standards to define the application of the appendices or annexes to which they apply. A 'normative' appendix or annex is an integral part of a Standard, whereas an 'informative' appendix or annex is only for information and guidance.

Contents

Preface	ii
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms, definitions, symbols and subscripts	1
3.1 Terms and definitions.....	1
3.1.1 General terms.....	1
3.2 Terms relating to quantities.....	3
3.3 Symbols and subscripts.....	9
4 Pump measurements and acceptance criteria	10
4.1 General.....	10
4.2 Guarantees.....	11
4.3 Measurement uncertainty.....	11
4.3.1 General.....	11
4.3.2 Fluctuations.....	12
4.3.3 Statistical evaluation of overall measurement uncertainty.....	12
4.4 Performance test acceptance grades and tolerances.....	15
4.4.1 General.....	15
4.4.2 Tolerances for pumps with an input power of 10 kW and below.....	16
4.4.3 Evaluation of flow and head.....	16
4.4.4 Evaluation of efficiency or power.....	18
4.5 Default test acceptance grades for pump application.....	21
5 Test procedures	22
5.1 General.....	22
5.2 Date of testing.....	22
5.3 Test programme.....	22
5.4 Testing equipment.....	22
5.5 Records and report.....	23
5.6 Test arrangements.....	23
5.7 Test conditions.....	23
5.7.1 Test procedure.....	23
5.7.2 Speed of rotation during test.....	23
5.8 NPSH tests.....	24
5.8.1 General.....	24
5.8.2 NPSH test types.....	24
6 Analysis	26
6.1 Translation of the test results to the guarantee conditions.....	26
6.1.1 Translation of the test results into data based on the specified speed of rotation and density.....	26
6.1.2 Test carried out with NPSHA different from that guaranteed.....	27
6.1.3 Performance curve.....	27
6.2 Obtaining specified characteristics.....	27
6.2.1 Reduction of impeller diameter.....	27
6.2.2 Requirement for retesting after reducing impeller diameters.....	27
Annex A (normative) Test arrangements	28
Annex B (informative) NPSH test arrangements	37
Annex C (informative) Calibration intervals	41
Annex D (informative) Measurement equipment	42

Annex E	(informative) Tests performed on the entire equipment set — String test	47
Annex F	(informative) Reporting of test results	50
Annex G	(informative) Special test methods	54
Annex H	(informative) Witnessed pump test	55
Annex I	(informative) Conversion to SI units	56
Annex J	(informative) Measurement uncertainty for NPSH test	58
Bibliography		59

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 9906 was prepared by Technical Committee ISO/TC 115, *Pumps*, Subcommittee SC 2, *Methods of measurement and testing*.

This second edition cancels and replaces the first edition (ISO 9906:1999), which has been technically revised.

Introduction

The tests in this International Standard are intended to ascertain the performance of the pump and to compare this with the manufacturer's guarantee.

The nominated guarantee for any quantity is deemed to have been met if, where tested according to this International Standard, the measured performance falls within the tolerance specified for the particular quantity (see [4.4](#)).

Australian Standard®

Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3

1 Scope

This International Standard specifies hydraulic performance tests for customers' acceptance of rotodynamic pumps (centrifugal, mixed flow and axial pumps, hereinafter "pumps").

This International Standard is intended to be used for pump acceptance testing at pump test facilities, such as manufacturers' pump test facilities or laboratories.

It can be applied to pumps of any size and to any pumped liquids which behave as clean, cold water.

This International Standard specifies three levels of acceptance:

- grades 1B, 1E and 1U with tighter tolerance;
- grades 2B and 2U with broader tolerance;
- grade 3B with even broader tolerance.

This International Standard applies either to a pump itself without any fittings or to a combination of a pump associated with all or part of its upstream and/or downstream fittings.

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 17769-1, *Liquid pumps and installation — General terms, definitions, quantities, letter symbols and units — Part 1: Liquid pumps*

ISO 17769-2, *Liquid pumps and installation — General terms, definitions, quantities, letter symbols and units — Part 2: Pumping system*

3 Terms, definitions, symbols and subscripts

3.1 Terms and definitions

For the purposes of this document, the terms, definitions, quantities and symbols given in ISO 17769-1 and 17769-2 and the following apply.

NOTE 1 [Table 1](#) gives an alphabetical list of the symbols used and [Table 2](#) gives a list of subscripts; see [3.3](#).

NOTE 2 All formulae are given in coherent SI units. For conversion of other units to SI units, see [Annex I](#).

3.1.1 General terms

NOTE All of the types of test in [3.1.1](#) apply to guarantee point to fulfil the customer's specification(s).

3.1.1.1

guarantee point

flow/head (Q/H) point, which a tested pump shall meet, within the tolerances of the agreed acceptance class

3.1.1.2

factory performance test

pump test performed to verify the initial performance of new pumps as well as checking for repeatability of production units, accuracy of impeller trim calculations, performance with special materials, etc.

Note 1 to entry: A typical performance test consists of the measurement of flow, head and power input to the pump or pump test motor. Additional measurements, such as NPSH, may be included as agreed upon. A factory test is understood to mean testing at a dedicated test facility, often at a pump manufacturer's plant or at an independent pump test facility.

3.1.1.3 non-witnessed pump test

3.1.1.3.1

factory test

test performed without the presence of a purchaser's representative, in which the pump manufacturer is responsible for the data collection and judgement of pump acceptance

Note 1 to entry: The advantage of this test is cost savings and accelerated pump delivery to the pump user. In many cases, if the purchaser is familiar with the performance of the pump (e.g. identical pump model order), a factory non-witnessed test may be acceptable.

3.1.1.3.2

signed factory test

test performed without the presence of a purchaser's representative, in which the pump manufacturer is responsible for compliance with the parameters of the agreed acceptance class

Note 1 to entry: The pump manufacturer conducts the test, passes judgement of pump acceptance and produces a signed pump test document. The advantage of this test is the same as seen on the non-witnessed test. Compared to a witnessed test, this test is substantially less expensive and often leads to accelerated pump delivery to the end user.

3.1.1.4 witnessed pump test

Note The witnessing of a pump test by a representative of the pump purchaser can serve many useful functions. There are various ways of witnessing a test.

3.1.1.4.1

witnessing by the purchaser's representative

testing physically attended by a representative of the purchaser, who signs off on the raw test data to certify that the test is performed satisfactorily

Note 1 to entry: It is possible for final acceptance of the pump performance to be determined by the witness. The benefit of witness testing depends largely on the effectiveness and expertise of the witness. A witness cannot only ensure the test is conducted properly, but also observes operation of the pump during testing prior to pump shipment to the job site. A disadvantage of witness testing can be extended delivery times and excessive cost. With just-in-time manufacturing methods, the scheduling of witness testing requires flexibility on the part of the witness and can lead to additional costs if the schedule of the witness causes delays in manufacturing.

3.1.1.4.2

remote witnessing by the purchaser's representative

pump performance testing witnessed from a distance by the purchaser or his/her representative

Note 1 to entry: With a remote camera system, the purchaser can monitor the entire testing remotely in real-time. The raw data, as recorded by the data acquisition system, can be viewed and analysed during the test, and the results can be discussed and submitted for approval. The advantages of this type of testing are savings in travel costs and accelerated pump delivery.

3.2 Terms relating to quantities

3.2.1

angular velocity

ω

number of radians of shaft rotation

Note 1 to entry: It is given by:

$$\omega = 2\pi n \quad (1)$$

Note 2 to entry: It is expressed in time, e.g. s⁻¹, where n is given in 60 × min⁻¹.

3.2.2

speed of rotation

number of rotations per second

3.2.3

mass flow rate

rate of flow discharged into the pipe from the outlet connection of the pump

Note 1 to entry: The mass flow rate is given in kilograms per second.

Note 2 to entry: The following losses or limiting effects are inherent to the pump:

- a) discharge necessary for hydraulic balancing of axial thrust;
- b) cooling of the pump bearings.

Note 3 to entry: Leakage from the fittings, internal leakage, etc., are not to be reckoned in the rate of flow. On the contrary, all derived flows for other purposes, such as

- a) cooling of the motor bearings, and
- b) cooling of a gear box (bearings, oil cooler)

are to be reckoned in the rate of flow.

Note 4 to entry: Whether and how these flows should be taken into account depends on the location of their derivation and of the section of flow-measurement respectively.

3.2.4

volume rate of flow

rate of flow at the outlet of the pump, given by:

$$Q = \frac{q}{\rho} \quad (2)$$

Note 1 to entry: In this International Standard, this symbol may also designate the volume rate of flow in any given section. It is the quotient of the mass rate of flow in this section by the density. (The section may be designated by subscripts.)

3.2.5

mean velocity

mean value of the axial speed of flow, given by:

$$U = \frac{Q}{A} \quad (3)$$

Note 1 to entry: Attention is drawn to the fact that in this case, Q may vary for different reasons across the circuit.

3.2.6**local velocity**

speed of flow at any given point

3.2.7**head**

energy of mass of liquid, divided by acceleration due to gravity, g , given by:

$$H = \frac{y}{g} \quad (4)$$

See [3.2.16](#).

3.2.8**reference plane**

any horizontal plane used as a datum for height measurement

Note 1 to entry: For practical reasons, it is preferable not to specify an imaginary reference plane.

3.2.9**height above reference plane**

height of the considered point above the reference plane

See [Figure A.1](#)

Note 1 to entry: Its value is:

- positive, if the considered point is above the reference plane;
- negative, if the considered point is below the reference plane.

3.2.10**gauge pressure**

pressure relative to atmospheric pressure

Note 1 to entry: Its value is:

- positive, if this pressure is greater than the atmospheric pressure;
- negative, if this pressure is less than the atmospheric pressure.

Note 2 to entry: All pressures in this International Standard are gauge pressures read from a manometer or similar pressure sensing instrument, except atmospheric pressure and the vapour pressure of the liquid, which are expressed as absolute pressures.

3.2.11**velocity head**

kinetic energy of the liquid in movement, divided by g , given by:

$$\frac{U^2}{2g} \quad (5)$$

3.2.12**total head**

overall energy in any section

Note 1 to entry: The total head is given by:

$$\frac{U^2}{2g} \quad (6)$$

where

z is the height of the centre of the cross-section above the reference plane;

p is the gauge pressure related to the centre of the cross-section.

Note 2 to entry: The absolute total head in any section is given by:

$$H_x = z_x + \frac{p_x}{\rho \times g} + \frac{U_x^2}{2 \times g} \quad (7)$$

3.2.13**inlet total head**

overall energy at the inlet section of the pump

Note 1 to entry: Inlet total head is given by:

$$H_1 = z_1 + \frac{p_1}{\rho \times g} + \frac{U_1^2}{2g} \quad (8)$$

3.2.14**outlet total head**

overall energy at the outlet section of the pump

Note 1 to entry: Outlet total head is given by:

$$H_2 = z_2 + \frac{p_2}{\rho \times g} + \frac{U_2^2}{2g} \quad (9)$$

3.2.15**pump total head**

algebraic difference between the outlet total head, H_2 , and the inlet total head, H_1

Note 1 to entry: If compressibility is negligible, $H = H_2 - H_1$. If the compressibility of the pumped liquid is significant, the density, ρ , should be replaced by the mean value:

$$H_2 = z_2 + \frac{p_2}{\rho \times g} + \frac{U_2^2}{2g} \quad (10)$$

and the pump total head should be calculated by [Formula \(12\)](#):

$$\rho_m = \frac{\rho_1 + \rho_2}{2} \quad (11)$$

Note 2 to entry: The correct mathematical symbol is H_{1-2} .

3.2.16**specific energy**

energy of liquid, given by:

$$y = gH \quad (12)$$

3.2.17**loss of head at inlet**

difference between the total head of the liquid at the measuring point and the total head of the liquid in the inlet section of the pump

3.2.18**loss of head at outlet**

difference between the total head of the liquid in the outlet section of the pump and the total head of the liquid at the measuring point

3.2.19**pipe friction loss coefficient**

coefficient for the head loss by friction in the pipe

3.2.20**net positive suction head****NPSH**

absolute inlet total head above the head equivalent to the vapour pressure relative to the NPSH datum plane

Note 1 to entry: NPSH is given by:

$$\text{NPSH} = H_1 - z_D + \frac{p_{\text{amb}} - p_v}{\rho_1 \cdot g} \quad (13)$$

Note 2 to entry: This NPSH relates to the NPSH datum plane, whereas inlet total head relates to the reference plane.

Note 3 to entry: A derogation has been given to allow the use of the abbreviated term NPSH (upright and not bold) as a symbol in mathematical formulae as a consequence of its well-established, historical use in this manner.

3.2.20.1**NPSH datum plane**

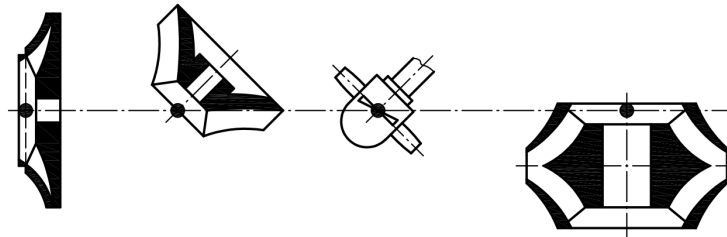
⟨multistage pumps⟩ horizontal plane through the centre of the circle described by the external points of the entrance edges of the impeller blades

3.2.20.2**NPSH datum plane**

⟨double inlet pumps with vertical or inclined axis⟩ plane through the higher centre

⟨double inlet pumps with vertical or inclined axis⟩ See [Figure 1](#)

Note 1 to entry: It is the responsibility of the manufacturer to indicate the position of this plane with respect to precise reference points on the pump.

**Key**

1 NPSH datum plane

Figure 1 — NPSH datum plane

3.2.21**available NPSH****NPSHA**

NPSH available as determined by the conditions of the installation for a specified rate of flow

Note 1 to entry: A derogation has been given to allow the use of the abbreviated term NPSHA (upright and not bold) as a symbol in mathematical formulae as a consequence of its well-established, historical use in this manner.

3.2.22 required NPSH NPSHR

minimum NPSH given by the manufacturer for a pump achieving a specified performance at the specified rate of flow, speed and pumped liquid (occurrence of visible cavitation, increase of noise and vibration due to cavitation, beginning of head or efficiency drop, head or efficiency drop of a given amount, limitation of cavitation erosion)

Note 1 to entry: A derogation has been given to allow the use of the abbreviated term NPSHR (upright and not bold) as a symbol in mathematical formulae as a consequence of its well-established, historical use in this manner.

3.2.23 NPSH3

NPSH required for a drop of 3 % of the total head of the first stage of the pump as standard basis for use in performance curves

Note 1 to entry: A derogation has been given to allow the use of the abbreviated term NPSH (upright and not bold) as a symbol in mathematical formulae as a consequence of its well-established, historical use in this manner.

3.2.24 type number

dimensionless quantity calculated at the point of best efficiency

Note 1 to entry: It is given by:

$$H_{1-2} \quad (14)$$

where

Q' is the volume rate of flow per eye;

H' is the head of the first stage;

n is given in s^{-1} .

Note 2 to entry: The type number is to be taken at maximum diameter of the first stage impeller.

3.2.25 pump power input

P_2
power transmitted to the pump by its driver

3.2.26 pump power output

hydraulic power at the pump discharge

Note 1 to entry: Pump power output is given by:

$$P_h = \rho Q g H = \rho Q \gamma \quad (15)$$

3.2.27 driver power input

P_{gr}
power absorbed by the pump driver

3.2.28 maximum shaft power

$P_{2,max}$
maximum pump shaft power, as set by the manufacturer, which is adequate to drive the pump over the specified operating conditions

3.2.29**pump efficiency**

pump power output divided by the pump power input

Note 1 to entry: Pump efficiency is given by:

$$\eta = \frac{P_h}{P_2} \quad (16)$$

3.2.30**overall efficiency**

pump power output divided by the driver power input

Note 1 to entry: Overall efficiency is given by:

$$\eta_{gr} = \frac{P_h}{P_{gr}} \quad (17)$$

3.3 Symbols and subscripts

Table 1 — Alphabetical list of basic letters used as symbols

Symbol	Quantity	Unit
A	Area	m ²
D	Diameter	m
e	Overall uncertainty, relative value	%
f	Frequency	s ⁻¹ , Hz
g	Acceleration due to gravity ^a	m/s ²
H	Pump total head	m
H_l	Losses in terms of head of liquid	m
k	Equivalent uniform roughness	m
K	Type number	Pure number
l	Length	m
M	Torque	Nm
n	Speed of rotation	s ⁻¹ , min ⁻¹
NPSH	Net positive suction head	m
p	Pressure	Pa
P	Power	W
q	Mass flow rate ^b	kg/s
Q	(Volume) rate of flow ^c	m ³ /s
Re	Reynolds number	Pure number
τ	Tolerance factor, relative value	%
t	Students distribution	Pure number
U	Mean velocity	m/s
v	Local velocity	m/s
V	Volume	m ³
y	Specific energy	J/kg
z	Height above reference plane	m
z_D	Difference between NPSH datum plane and reference plane (see 3.2.20)	m
η	Efficiency	Pure number
θ	Temperature	°C
λ	Pipe friction loss coefficient	Pure number
ν	Kinematic viscosity	m ² /s
ρ	Density	kg/m ³
ω	Angular velocity	rad/s

^a In principle, the local value of g should be used. Nevertheless, for grades 2 and 3, it is sufficient to use a value of 9,81 m/s². For the calculation of the local value $g = 9,780\,3\,(1 + 0,005\,3\,\sin^2\varphi) - 3 \times 10^{-6} \cdot Z$, where φ is the latitude and Z is the height above sea level.

^b An optional symbol for mass flow rate is q_m .

^c An optional symbol for volume rate of flow is q_v .

Table 2 — List of letters and figures used as subscripts

Subscript	Meaning
1	inlet
1'	inlet measuring section
2	outlet (except for P_2)
2'	outlet measuring section
abs	absolute
amb	ambient
D	difference, datum
f	liquid in measuring pipes
G	guaranteed
H	pump total head
h	hydraulic
gr	combined motor/pump unit (overall)
J	losses
M	manometer
n	speed of rotation
P	power
Q	(volume) rate of flow
ref	reference plane
sp	specified
T	translated, torque
v	vapour (pressure)
η	efficiency
x	at any section

4 Pump measurements and acceptance criteria

4.1 General

The specified and contractually agreed upon rated point (duty point), hereinafter "the guarantee point", shall be evaluated against one acceptance grade and its corresponding tolerance. For a pump performance test, this guarantee point shall always specify the guaranteed flow, Q_G , and guaranteed head, H_G , and may, optionally, specify guaranteed efficiency, guaranteed shaft power or guaranteed net positive suction head required (NPSHR). Where applicable, these optional guarantee parameters need to be specified for those tests, see respective tests in [4.4.3](#) and [5.8](#).

The acceptance grade tolerance applies to the guarantee point only. Other specified duty points, including their tolerances, shall be by separate agreement between the manufacturer and purchaser. If other specified duty points are agreed upon, but no tolerance is given for these points, the default acceptance level for these points shall be grade 3.

A guarantee point may be detailed in a written contract, a customer-specific pump performance curve or similar written and project specific documentation.

If not otherwise agreed upon between the manufacturer and the purchaser, the following shall apply.

- The acceptance grade shall be in accordance with the grades given in [Table 8](#).
- Tests shall be carried out on the test stand of the manufacturer's works with clean, cold water using the methods and test arrangements specified in this International Standard.

- c) The pump performance shall be guaranteed between the pump's inlet connection and outlet connection.
- d) Pipe and fittings (bends, reducers and valves) outside of the pump are not a part of the guarantee.

The combination of manufacturing and measurement tolerances in practice necessitates the usage of tolerances on tested values. The tolerances given in [Table 8](#) take into account both manufacturing and measurement tolerances.

The performance of a pump varies substantially with the nature of the liquid being pumped. Although it is not possible to give general rules whereby performance with clean, cold water can be used to predict performance with other liquids, it is desirable for the parties to agree on empirical rules to suit the particular circumstances. For further information, see ISO/TR 17766.

If a number of identical pumps are being purchased, the number of pumps to be tested shall be agreed between the purchaser and manufacturer.

Both the purchaser and manufacturer shall be entitled to witness the testing. If tests are not carried out at the manufacturer's test stand, opportunity shall be allowed for verification of the pump installation and instrumentation adjustments by both parties.

4.2 Guarantees

The manufacturer guarantees that, for the guarantee point and at the rated speed (or in some cases frequency and voltage), the measured pump curve touches, or passes through a tolerance surrounding the guarantee point, as defined by the applicable acceptance grade (see [Table 8](#) and [Figures 2](#) and [3](#)).

A guarantee point shall be defined by a guaranteed flow, Q_G , and a guaranteed head, H_G .

In addition, one or more of the following quantities may be guaranteed at the specified conditions and at the rated speed:

- a) as defined in [4.4.3](#) and [Figures 4](#), [5](#) and [6](#),
 - 1) the minimum pump efficiency, η_G , or the maximum pump input power, P_G , or
 - 2) in the case of a combined pump and motor unit, the minimum combined efficiency, η_{grG} , or the maximum pump motor unit input power, P_{grG} .
- b) the maximum NPSHR at the guarantee flow.

The maximum power input may be guaranteed for the guarantee point or for a range of points along the pump curve. This, however, can require larger tolerances to be agreed upon between the purchaser and manufacturer.

4.3 Measurement uncertainty

4.3.1 General

Every measurement is inevitably subject to some uncertainty, even if the measuring procedures and the instruments used, as well as the methods of analysis, fully comply with good practice and with the requirements of this International Standard.

The guidance and procedures described in [4.3.2](#) and [4.3.3](#) are intended to provide general information to the user, as well as practical procedures allowing the user to estimate measurement uncertainty with reasonable confidence in applying the testing in conformity with this International Standard.

NOTE For comprehensive information on measurement uncertainty, see ISO/IEC Guide 99 and associated documents.

4.3.2 Fluctuations

Where the design or operation of a pump is such that fluctuations of great amplitude are present, measurements may be carried out by providing a damping device in the measuring instruments or their connecting lines, which is capable of reducing the amplitude of the fluctuations to within the values given in [Table 3](#). A symmetrical and linear damping device shall be used, for example a capillary tube, which shall provide integration over at least one complete cycle of fluctuations.

Table 3 — Permissible amplitude of fluctuation as a percentage of mean value of quantity being measured

Measured quantity	Permissible amplitude of fluctuations		
	Grade 1	Grade 2	Grade 3
	%	%	%
Rate of flow	±2	±3	±6
Differential head	±3	±4	±10
Outlet head	±2	±3	±6
Inlet head	±2	±3	±6
Input power	±2	±3	±6
Speed of rotation	±0,5	±1	±2
Torque	±2	±3	±6
Temperature	0,3 °C	0,3 °C	0,3 °C

4.3.3 Statistical evaluation of overall measurement uncertainty

4.3.3.1 The estimate of the random component (random uncertainty)

The random component due either to the characteristics of the measuring system or to variations of the measured quantity or both appears directly as a scatter of the measurements. Unlike the systematic uncertainty, the random component can be reduced by increasing the number of measurements of the same quantity under the same conditions.

A set of readings not less than three (3) shall be taken at each test point. The random component, e_R , shall be calculated as follows:

The estimate of the random component of measurement uncertainty is calculated from the mean and the standard deviation of the observations. For the uncertainty of the readings, replace x with the actual measurement readings of flow, Q , head, H , and power, P .

If n is the number of readings, the arithmetic mean, $K = \frac{2 \pi n Q^{1/2}}{(gH')^{3/4}} = \frac{\omega Q^{1/2}}{y^{3/4}}$, of a set of repeated observations x_i ($i=1...n$) is

$$P_h = \rho Q g H = \rho Q y \quad (18)$$

The standard deviation, s , of these observations is given by:

$$\eta = \frac{P_h}{P_2} \quad (19)$$

The relative value of the uncertainty, e_R , of the mean due to random effects is given by:

$$\eta_{gr} = \frac{P_h}{P_{gr}} \quad (20)$$

where t is a function of n as given in [Table 4](#).

NOTE 1 If the value of the overall uncertainty, e , does not meet the criteria given in [Table 7](#), the value of the random component, e_R , of the measurement can be reduced by increasing the number of measurements of the same quantity under the same conditions.

NOTE 2 The random component, as defined in this International Standard, is classified as Type A uncertainty (see ISO/IEC Guide 99).

Table 4 — Values of Student's t -distribution
(based on 95 % confidence level)

n	t	n	t
3	4,30	12	2,20
4	3,18	13	2,18
5	2,78	14	2,16
6	2,57	15	2,14
7	2,45	16	2,13
8	2,36	17	2,12
9	2,31	18	2,11
10	2,26	19	2,10
11	2,23	20	2,09

4.3.3.2 The estimate of the instrumental measurement uncertainty (systematic uncertainties)

After all known errors have been removed by zero adjustment, calibration, careful measurement of dimensions, proper installation, etc., there remains an uncertainty which never disappears. This uncertainty cannot be reduced by repeating the measurements if the same instrument and the same method of measurement are used.

The estimate of the systematic uncertainty of the uncertainty, e_s , is in practice based on calibration traceable to international measurement standards. Permissible relative values for the systematic uncertainty in this International Standard are given in [Table 5](#).

Table 5 — Permissible relative values of the instrumental uncertainty, e_s

Measured quantity	Maximum permissible systematic uncertainty (at guarantee point)	
	Grade 1 %	Grades 2 and 3 %
Rate of flow	±1,5	±2,5
Differential head	±1,0	±2,5
Outlet head	±1,0	±2,5
Inlet head	±1,0	±2,5
Suction head for NPSH testing	±0,5 ^a	±1,0
Driver power input	±1,0	±2,0
Speed of rotation	±0,35	±1,4
Torque	±0,9	±2,0
^a See Annex J for explanation.		

4.3.3.3 The overall uncertainty

The value for overall uncertainty, e , is given by:

$$e = \sqrt{e_R^2 + e_S^2} \quad (21)$$

Permissible values of overall measurement uncertainties, e , are given in [Table 6](#).

NOTE The overall uncertainty, as defined in this International Standard, is equated with expanded measurement uncertainty (see ISO/IEC Guide 99).

Table 6 — Permissible values of overall uncertainties

Quantity	Symbol	Grade 1 %	Grades 2, 3 %
Flow rate	e_Q	±2,0	±3,5
Speed of rotation	e_n	±0,5	±2,0
Torque	e_T	±1,4	±3,0
Pump total head	e_H	±1,5	±3,5
Driver power input	e_{pgr}	±1,5	±3,5
Pump power input (computed from torque and speed of rotation)	e_p	±1,5	±3,5
Pump power input (computed from driver power and motor efficiency)	e_p	±2,0	±4,0