INTERNATIONAL STANDARD

ISO 9906

First edition
1999-12-15

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

Pompes rotodynamiques — Essais de fonctionnement hydraulique pour la réception — Niveaux 1 et 2

Reference number
ISO 9906:1999(E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

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 3.

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.

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

This first edition of ISO 9906 cancels and replaces ISO 2548:1975 and ISO 3555:1977, which have been combined and technically revised (see Introduction).

Annexes A, B and C form a normative part of this International Standard. Annexes D to K are for information only.

Introduction

This International Standard combines and replaces the former acceptance test standards ISO 3555:1977 (corresponding to grade 1 of this International Standard) and ISO 2548:1975 (corresponding to grade 2 of this International Standard), but there is an important change in the verification of guarantees, because the uncertainty of measurement must not influence the acceptability of a pump and the tolerances are due to constructional differences only.

New tolerance factors have been introduced to ensure as far as possible that a pump which was acceptable under the previous International Standards (ISO 2548 and/or ISO 3555) would also be acceptable under this International Standard.

Contrary to this International Standard, ISO 5198 is not to be understood as an acceptance test code. It gives guidance for measurements of very high accuracy and for the thermodynamic method for direct measurement of efficiencies, but it does not recommend verification of guarantees.

Terms used in this International Standard such as “guarantee” or “acceptance” should be understood in a technical but not in a legal sense. The term “guarantee” therefore specifies values for checking purposes determined in the contract, but does not say anything about the rights or duties arising, if these values are not reached or fulfilled. The term “acceptance” does not have any legal meaning here, either. Therefore, an acceptance test carried out successfully alone does not represent an “acceptance” in the legal sense.

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

1 Scope

This International Standard specifies hydraulic performance tests for acceptance of rotodynamic pumps (centrifugal, mixed flow and axial pumps, hereinafter simply designated as “pumps”). It is applicable to pumps of any size and to any pumped liquids behaving as clean cold water (such as defined in 5.4.5.2). It is neither concerned with the structural details of the pump nor with the mechanical properties of their components.

This International Standard contains two grades of accuracy of measurement: grade 1 for higher accuracy, and grade 2 for lower accuracy. These grades include different values for tolerance factors, for allowable fluctuations and uncertainties of measurement.

For pumps produced in series with selection made from typical performance curves and for pumps a with power input of less than 10 kW, see annex A for higher tolerance factors.

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1438-1, *Water flow measurement in open channels using weirs and Venturi flumes — Part 1: Thin-plate weirs.*

ISO 2186, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements.*

ISO 3354, *Measurement of clean water flow in closed conduits — Velocity-area method using, current-meters in full conduits and under regular flow conditions.*

ISO 3966, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes.*

ISO 4373, *Measurement of liquid flow in open channels — Water-level measuring devices.*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 5198, *Centrifugal, mixed flow and axial pumps — Code for hydraulic performance tests — Precision grade.*

ISO 7194, *Measurement of fluid flow in closed conduits — Velocity-area methods of flow measurement in swirling or asymmetric flow conditions in circular ducts by means of current-meters or Pitot-static tubes.*

ISO 8316, *Measurement of liquid flow in closed conduits — Method by collection of the liquid in a volumetric tank.*

ISO 9104, *Measurement of liquid flow in closed conduits — Methods of evaluating the performance of electro-magnetic flow-meters for liquids.*

IEC 60034-2, *Recommendations for rotating electrical machinery (excluding machines for traction vehicles) — Part 2: Determination of efficiency of rotating electrical machinery.*

IEC 60051, *Recommendations for direct acting electrical measuring instruments and their accessories.*

3 Terms, definitions and symbols

For the purposes of this International Standard, the following terms, definitions and symbols apply.

NOTE 1 The definitions, particularly those given for head and net positive suction head (NPSH), may not be appropriate for general use in hydrodynamics, and are for the purposes of this International Standard only. Some terms in current use but not strictly necessary for the use of this International Standard are not defined.

NOTE 2 Table 1 gives an alphabetical list of symbols used, and Table 2 gives a list of subscripts. In this International Standard all formulae are given in coherent SI units. For conversion of other units to SI units, see annex D.

NOTE 3 In order to avoid any error of interpretation, it is deemed desirable to reproduce the definitions of quantities and units as given in ISO 31 and to supplement these definitions by some specific information on their use in this International Standard.

3.1
angular velocity
number of radians of a shaft per unit time

$$\omega = 2\pi n$$

3.2
speed of rotation
number of rotations per unit time

3.3
density
mass per unit volume

3.4
pressure
force per unit area

NOTE In this International Standard all pressures are gauge pressures, i.e. measured with respect to the atmospheric pressure, except for atmospheric pressure and the vapour pressure which are absolute pressures.

3.5
power
energy transferred per unit time

3.6
Reynolds number

$$Re = \frac{UD}{\nu}$$

3.7
mass flow rate
external mass flow rate of the pump, i.e. the rate of flow discharged into the pipe from the outlet branch of the pump

NOTE 1 The following losses or abstractions are inherent to the pump:

a) discharge necessary for hydraulic balancing of axial thrust;

b) cooling of bearings of the pump itself;

c) liquid seal to the packing.

NOTE 2 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

— cooling of the motor bearings;

— cooling of a gear box (bearings, oil cooler), etc.

are to be reckoned in the rate of flow.

NOTE 3 Whether and how these flows are to be taken into account depends on the location of their derivation and of the section of flow-measurement, respectively.

3.8
volume flow rate
outlet volume flow rate has the following value:

$$Q = \frac{q}{\rho}$$

NOTE In this International Standard the symbol Q may also designate the volume flow rate in any given section. It is the quotient of the mass flow rate in this section and the density. (The section may be designated by subscripts.)

3.9
mean velocity
mean axial velocity of flow equal to the volume flow rate divided by the pipe cross section area

$$U = \frac{Q}{A}$$

NOTE Attention is drawn to the fact that in this case Q may vary for different reasons across the circuit.

3.10
local velocity
velocity of flow at any point

3.11
head
energy per unit mass of fluid, divided by acceleration due to gravity, g

3.12
reference plane
any horizontal plane used as a datum for height measurement

NOTE For practical reasons it is preferable not to specify an imaginary reference plane.

3.13
height above reference plane
height of the considered point above the reference plane

NOTE Its value is:

— positive, if the considered point is above the reference plane;

— negative, if the considered point is below the reference plane.

See Figures 3 and 4.

3.14
gauge pressure
pressure relative to atmospheric pressure

NOTE 1 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 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.

3.15
velocity head
kinetic energy per unit mass of the liquid in movement, divided by g:

$$\frac{U^2}{2g}$$

3.16
total head
in any section, the total head is given by:

$$H_x = z_x + \frac{p_x}{\rho g} + \frac{U_x^2}{2g}$$

where z is the height of the centre of the cross-section above the reference plane and p is the gauge pressure related to the centre of the cross-section

NOTE The absolute total head in any section is given by:

$$H_{x(\text{abs})} = z_x + \frac{p_x}{\rho g} + \frac{p_{\text{amb}}}{\rho g} + \frac{U_x^2}{2g}$$

3.17
inlet total head
total head in the inlet section of the pump:

$$H_1 = z_1 + \frac{p_1}{\rho g} + \frac{U_1^2}{2g}$$

3.18
outlet total head
total head in the outlet section of the pump:

$$H_2 = z_2 + \frac{p_2}{\rho g} + \frac{U_2^2}{2g}$$

3.19
pump total head
algebraic difference between the outlet total head H_2 and the inlet total head H_1

NOTE 1 If the 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:

$$\rho_{\text{m}} = \frac{\rho_1 + \rho_2}{2}$$

and the pump total head should be calculated by the formula:

$$H = z_2 - z_1 + \frac{p_2 - p_1}{\rho_m \cdot g} + \frac{U_2^2 - U_1^2}{2g}$$

NOTE 2 The mathematically correct symbol would be $H_{1\text{-}2}$.

3.20
specific energy
energy per unit mass of liquid:

$$y = gH$$

3.21
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

3.22
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

3.23
pipe friction loss coefficient
coefficient for the head loss by friction in the pipe

3.24
net positive suction head
NPSH
absolute inlet total head above the head equivalent to the vapour pressure relative to the NPSH datum plane:

$$\text{NPSH} = H_1 - z_D + \frac{p_{amb} - p_v}{\rho_1 \, g}$$

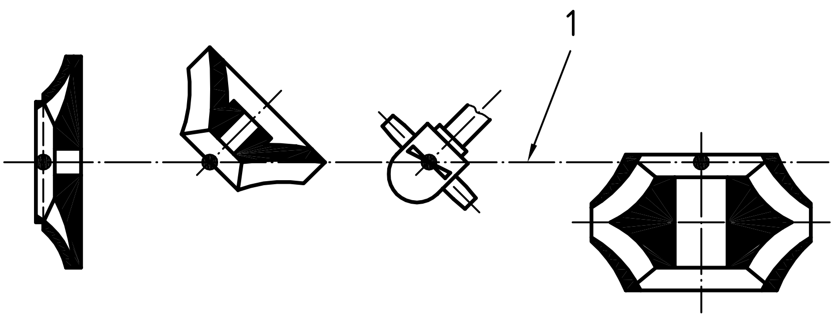
NOTE This NPSH relates to the NPSH datum plane, whereas the inlet total head relates to the reference plane.

3.25
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

3.26
NPSH datum plane
<double inlet pumps with vertical or inclined axis> plane through the higher centre

NOTE The manufacturer should indicate the position of this plane with respect to precise reference points on the pump.

See Figure 1.



Key

1 NPSH datum plane

Figure 1 — NPSH datum plane

3.27
available NPSH
NPSHA
NPSH available as determined by the conditions of the installation for a specified flow rate

3.28
required NPSH
NPSHR
minimum NPSH given by the manufacturer/supplier for a pump achieving a specified performance at a specified flow rate, 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)

3.29
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

3.30
type number
dimensionless quantity calculated at the point of best efficiency which is defined by the following formula:

$$K = \frac{2\pi n Q'^{1/2}}{(gH')^{3/4}} = \frac{\omega Q'^{1/2}}{y'^{3/4}}$$

where Q' is the volume rate of flow per eye and H' is the head of the first stage

NOTE The type number is to be taken at maximum diameter of the first stage impeller.

3.31
pump power input
power transmitted to the pump by its driver

3.32
pump power output
mechanical power transferred to the liquid during its passage through the pump:

$$P_u = \rho\, Q\, g\, H = \rho\, Q\, y$$

3.33
driver power input
power absorbed by the pump driver

3.34
pump efficiency
pump power output divided by the pump power input

$$\eta = \frac{P_u}{P}$$

3.35
overall efficiency
pump power output divided by the driver power input

$$\eta_{gr} = \frac{P_u}{P_{gr}}$$

Table 1 — Alphabetical list of basic letters used as symbols

Symbol	Quantity	Unit
A	Area	m^2
D	Diameter	m
E	Energy	J
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_J	Losses in terms of head of liquid	m
k	Equivalent uniform roughness	m
K	Type number	(pure number)
l	Length	m
m	Mass	kg
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 flow rate [c]	m^3/s
Re	Reynolds number	(pure number)
t	Tolerance factor, relative value	%
t	Time	s
T	Torque	Nm
U	Mean velocity	m/s
v	Local velocity	m/s
V	Volume	m^3
y	Specific energy	J/kg
z z_D	Height above reference plane Difference between NPSH datum plane (see 3.25) and reference plane	m 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 grade 2 it is sufficient to use a value of 9,81 m/s^2. 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 altitude.

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

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

Table 2 — List of letters and figures used as subscript

Subscript	Meaning
1	inlet
1′	inlet measuring section
2	outlet
2′	outlet measuring section
abs	absolute
amb	ambient
D	difference, datum
f	fluid in measuring pipes
G	guaranteed
H	pump total head
gr	combined motor/pump unit (overall)
m	mean
M	manometer
n	speed of rotation
P	power
Q	(volume) flow rate
sp	specified
T	translated, torque
u	useful
v	vapour (pressure)
η	efficiency
x	at any section

4 Guarantees

4.1 Subjects of guarantees

One guarantee point shall be defined by a guarantee flow Q_G and a guarantee head H_G.

The manufacturer/supplier guarantees that under the specified conditions and at the specified speed (or in some cases frequency and voltage) the measured $H(Q)$ curve will pass through a range of tolerance (see Table 10 and Figure 2), surrounding the guarantee point.

Other tolerance ranges (e.g. only given by positive tolerance factors) may be agreed upon in the contract.

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

a) the pump efficiency, η_G, or in the case of overall pump driver unit, the combined efficiency, η_{grG};

b) the required net positive suction head (NPSHR) at the guarantee flow;

} at the flow rate which is defined in 6.4.2 and Figure 2.

By special agreement several guarantee points and the appropriate values of efficiency and required net positive suction head at reduced or increased flow rates may be guaranteed. The maximum power input may be guaranteed for the guarantee flow or for a range of operation. This, however, may require larger tolerance ranges to be agreed upon between the purchaser and manufacturer/supplier.

4.2 Other conditions of guarantee

Unless otherwise agreed, the following conditions shall apply to the guaranteed values.

a) Unless the chemical and physical properties of the liquid being pumped are stated, the guarantee points shall apply to clean cold water (see 5.4.5.2).

b) The relationship between the guarantee values under clean cold water conditions and the likely performance under other liquid conditions shall be agreed in the contract.

c) Guarantees shall apply only to the pump as tested by the methods and in the test arrangements specified in this International Standard.

d) The pump manufacturer/supplier shall not be responsible for the specification of the guarantee point.

5 Execution of tests

5.1 Subjects of tests

5.1.1 General

If not otherwise agreed between the manufacturer/supplier and the purchaser, the following shall apply:

a) accuracy according to grade 2;

b) tests shall be carried out on the test stand of the manufacturer's works;

c) the NPSH test is not included.

Any deviations from this shall be agreed between the purchaser and manufacturer/supplier. This should be done as soon as possible, and should preferably form part of the contract.

Among others, such deviations may be:

— accuracy according to grade 1;

— no negative tolerance factors (see 4.1);

— tolerance factors corresponding to annex A;

— statistical evaluation of measurement results according to annex I;

— tests in a neutral laboratory or on site;

— deviations from the requirements concerning the installation of the pump and the measuring apparatus;

— simulated construction of pumps (e.g. several rotors in same casing);

— a requirement for the NPSH test.

Annex K shows a checklist of items where agreement between the purchaser and manufacturer/supplier is recommended.

5.1.2 Contractual tests — Fulfilment of the guarantee

The tests are intended to ascertain the performance of the pump and to compare this with the manufacturer’s/supplier's guarantee.

The nominated guarantee for any quantity shall be deemed to have been met if, when tested according to this International Standard, the measured performance fails within the tolerance specified for the particular quantity (see clause 6).

When NPSHR is to be guaranteed, the type of test shall be specified (see 11.1.2).

When a number of identical pumps are to be purchased, the number of pumps to be tested shall be agreed between the purchaser and manufacturer/supplier.

5.1.3 Additional checks

During the test, it may be noted if the behaviour of the pump is satisfactory in respect of the temperature of packings and bearings, of leakage of air or water, of acoustic emission and of vibrations[1].

5.2 Organization of tests

5.2.1 General

Both, purchaser and manufacturer/supplier shall be entitled to witness these tests.

5.2.2 Location of tests

5.2.2.1 Works tests

Performance tests should preferably be carried out at the manufacturer’s works, or at a place to be mutually agreed between the manufacturer/supplier and the purchaser.

5.2.2.2 Site tests

Special agreement is necessary for performance tests on site providing all the requirements of this International Standard can be satisfied. It is, however, recognised that the conditions at most sites often preclude full compliance with this International Standard. In these instances site performance tests may still be acceptable providing the parties have agreed how allowance is made for the inaccuracies which will inevitably result from departure from the specified requirement.

1) Special International Standards for pumps are under study in ISO/TC 115.