INTERNATIONAL STANDARD

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

Pompes rotodynamiques — Essais de fonctionnement hydraulique pour la réception — Niveaux 1, 2 et 3

Reference number
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Foreword

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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).

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 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 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 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 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 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 It is given by:

$$\omega = 2\pi n \tag{1}$$

NOTE 2 It is expressed in time, e.g. s^{-1}, where n is given in $60 \times min^{-1}$.

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 The mass flow rate is given in kilograms per second.

NOTE 2 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 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 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:

$$Q = \frac{q}{\rho} \tag{2}$$

NOTE 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:

$$U = \frac{Q}{A} \tag{3}$$

NOTE 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 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 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 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.

3.2.11
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 The total head is given by:

$$H_x = z_x + \frac{p_x}{\rho \times g} + \frac{U_x^2}{2 \times g} \quad (6)$$

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 The absolute total head in any section is given by:

$$H_{x(\text{abs})} = z_x + \frac{p_x}{\rho \times g} + \frac{p_{\text{amb}}}{\rho \times g} + \frac{U_x^2}{2g} \qquad (7)$$

3.2.13
inlet total head
overall energy at the inlet section of the pump

NOTE Inlet total head is given by:

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

3.2.14
outlet total head
overall energy at the outlet section of the pump

NOTE Outlet total head is given by:

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

3.2.15
pump total head
algebraic difference between the outlet total head, H_2, and the inlet total head, H_1

NOTE 1 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:

$$\rho_{\text{m}} = \frac{\rho_1 + \rho_2}{2} \qquad (10)$$

and the pump total head should be calculated by Formula (12):

$$H = z_2 - z_1 + \frac{p_2 - p_1}{\rho_{\text{m}} \cdot g} + \frac{U_2^2 - U_1^2}{2g} \qquad (11)$$

NOTE 2 The correct mathematical symbol is $H_{1\text{–}2}$.

3.2.16
specific energy
energy of liquid, given by:

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

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 NPSH is given by:

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

NOTE 2 This NPSH relates to the NPSH datum plane, whereas inlet total head relates to the reference plane.

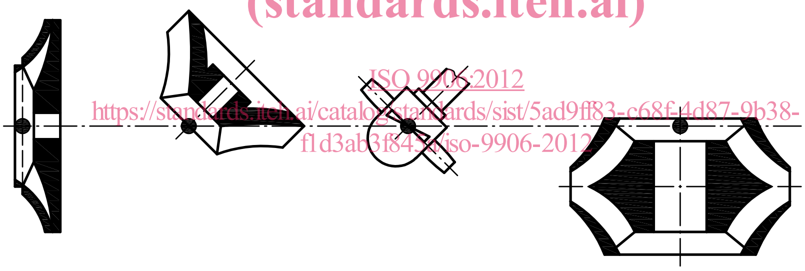
NOTE 3 A derogation has been given to allow the use of the abbreviated term NPSH (upright and not bold) as a symbol in mathematical formulae as a consequence of its well-established, historical use in this manner.

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

See Figure 1.

NOTE 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 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 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 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 It is given by:

$$K = \frac{2\,\pi n\,Q'^{1/2}}{(gH')^{3/4}} = \frac{\omega\,Q'^{1/2}}{y'^{3/4}} \tag{14}$$

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 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 Pump power output is given by:

$$P_h = \rho Q g H = \rho Q y \tag{15}$$

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 Pump efficiency is given by:

$$\eta = \frac{P_h}{P_2} \tag{16}$$

3.2.30
overall efficiency
pump power output divided by the driver power input

NOTE Overall efficiency is given by:

$$\eta_{\mathrm{gr}} = \frac{P_{\mathrm{h}}}{P_{gr}} \qquad (17)$$

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_J	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/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 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.