

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS B 8301 : 2000

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

ICS 23.080

Descriptors : centrifugal pumps, rotary pumps, axial-flow pumps, performance testing,
flow measurement

Reference number : JIS B 8301 : 2000 (E)

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of International Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently **JIS B 8301 : 1990** is replaced with **JIS B 8301 : 2000**. **JIS B 8303 : 1990** *Testing methods for boiler feed pumps*, **JIS B 8304 : 1990** *Testing methods for condensate pumps*, and **JIS B 8305 : 1990** *Testing methods for self-priming centrifugal pumps* are included in this Standard and therefore have been withdrawn and replaced with this Standard.

This revision is made based on the International Standards for conformity of the Japanese Industrial Standard with the International Standard.

Date of Establishment: 1952-08-25

Date of Revision: 2000-07-20

Date of Public Notice in Official Gazette: 2000-07-21

Investigated by: Japanese Industrial Standards Committee
Divisional Council on General Machinery

JIS B 8301:2000 First English edition published in 2001-07

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2001

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

Contents

	Page
Introduction	1
1 Scope	1
2 Normative references	1
3 Terms, definitions and symbols	3
3.1 Terms, definitions, symbols and units	3
3.2 Basic symbols and subscripts	8
4 Guarantees	8
4.1 Subjects of guarantees	8
4.2 Other conditions of guarantee	9
5 Execution of tests	9
5.1 Subjects of tests	9
5.2 Organization of tests	10
5.3 Test arrangements	12
5.4 Test conditions	14
6 Analysis of test results	19
6.1 Translation of the test results to the guarantee conditions	19
6.2 Measuring uncertainties	20
6.3 Values of tolerance factors	22
6.4 Verification of guarantees	23
6.5 Obtaining specified characteristics	24
7 Measurement of flow rate	25
8 Measurement of pump total head	25
8.1 General	25
8.2 Definition of the measuring sections	28
8.3 Water level measurement	32
8.4 Pressure measurements	32
9 Measurement of speed of rotation	36
10 Measurement of pump power input	37
10.1 Measurement of torque	37
10.2 Electric power measurement	37
10.3 Special cases	37

11 Cavitation tests	38
11.1 General.....	38
11.2 Test installations	41
11.3 Determination of the NPSH required by the pump	42
Annex A (normative) Tolerance factors for pumps produced in series with selection made from typical performance curves and for pumps with a driver power input less than 10 kW	45
Annex B (normative) Determination of reduced impeller diameters	46
Annex C (normative) Correction of friction losses	47
Annex D (informative) Conversion to SI units	52
Annex E (informative) Guide for suitable time periods between calibrations of test instruments	53
Annex F (informative) Costs and repetition of tests	54
Annex G (informative) Performance correction chart for viscous liquids	55
Annex H (informative) NPSHR reduction for pumps handling hydro- carbon liquids and high temperature water	58
Annex I (informative) Statistical evaluation of measurement results	60
Annex J (informative) Pump test sheet.....	62
Annex K (informative) Checklist	63
Annex L (normative) Measurement of flow rate	64
Annex 1 (informative) Test arrangements	67
Annex 2 (informative) Operating conditions, hydraulic pressure resistance and temperature rise at minimum discharge	70
Annex 3 (informative) Testing methods for self-priming ability of self-priming centrifugal pumps	73
Fig. 1 Verification of guarantee on flow rate, head and efficiency	24
Fig. 2 Determination of pump total head	26
Fig. 3 Isometric illustration of the determination of pump total head	27
Fig. 4 Correction of inlet total head	29
Fig. 5 Pressure tapping perpendicular to the plane of the volute or to the plane of a bend	29
Fig. 6 Measurement of pump total head for various types of submerged pumps	31
Fig. 7 Pressure tapping for grade 1 and 2 tests	33

Fig. 8 Requirements for static pressure tapplings	33
Fig. 9 Determination of pump total head by differential manometer	35
Fig. 10 Reference plane of spring pressure gauges	36
Fig. 11 Method of determining NPSH3	40
Fig. 12 Cavitation tests: Variation of NPSH by means of a closed loop controlling pressure and/or temperature	43
Fig. 13 Cavitation tests: Variation of NPSH by control of liquid level at pump inlet sump	44
Fig. 14 Cavitation tests: Variation of NPSH by means of an inlet pressure control valve	44
Fig. B.1 Reduced impeller diameters	46
Fig. C.1 Chart for grade 1 tests showing velocities above which loss corrections are required (for measuring sections placed 2D upstream and downstream of the pump flanges)	48
Fig. C.2 Chart for grade 2 tests showing velocities above which loss corrections are required (for measuring sections placed 2D upstream and downstream of the pump flanges)	49
Fig. C.3 Universal coefficient for head loss	50
Fig. C.4 Values of universal coefficient for head loss (Moody chart)	51
Fig. G.1 Performance correction chart for viscous liquids	57
Fig. H.1 NPSHR reduction for pumps handling hydrocarbon liquids and high temperature water	59
Annex 1 Fig. 1 Test arrangements (Example 1)	67
Annex 1 Fig. 2 Test arrangements (Example 2)	67
Annex 1 Fig. 3 Test arrangements for boiler feed centrifugal pumps	68
Annex 1 Fig. 4 Test arrangements for condensate pumps	69
Annex 2 Fig. 1 Standard values of vibration	70
Annex 3 Fig. 1 Self-priming test arrangements	73
Annex 3 Fig. 2 Suction condition	73
Related standards	75
Table 1 Terms, definitions, symbols and units	4
Table 2 Alphabetical list of basic letters used as symbols	8
Table 3 List of letters and figures used as subscript	8
Table 4 Permissible amplitude of fluctuations as a percentage of mean value of quantity being measured	15

Table 5	Limits of variations between repeated measurements of the same quantity (based on 95 % confidence limits)	17
Table 6	Specification of clean cold water	18
Table 7	Characteristics of liquids	18
Table 8	Permissible values of systematic uncertainties	21
Table 9	Permissible values of overall measurement uncertainties	22
Table 10	Resulting values of the overall uncertainties of efficiency	22
Table 11	Values of tolerance factors	23
Table C.1	Equivalent uniform roughness for pipes	47
Table D.1	Conversion factors	52
Table E.1	Suitable time periods between calibration of test instruments..	53
Table G.1	Additional symbols and definitions used in Annex G	55
Table I.1	Additional symbols	60
Annex 2 Table 1	<u>Permissible maximum temperature and permissible temperature rise of bearing</u>	71

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

Introduction This Japanese Industrial Standard has been prepared based on **ISO 9906 Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1 and 2**, published in 1999 without modifying its technical contents. However, regarding clause **7 Measurement of flow rate**, the methods which have been specified in the former Japanese Industrial Standard are added. Some items not specified in the corresponding International Standard have been additionally contained as Japanese Industrial Standard. Concerning insertion of an independent sub-clause, a capital alphabetical letter is added to the clause number immediately before the position of insertion to form its clause number.

The portions underlined with dots in this Standard show the matters not specified in the original International Standard.

1 Scope This Standard specifies hydraulic performance tests for acceptance of rotodynamic pumps (centrifugal pumps, mixed flow pumps and axial flow pumps, hereafter referred to as “pumps”). It is applicable to pumps of any size, and to any pumped liquids behaving as clean cold water (such as defined in **5.4.5.1**). It is neither concerned with the structural details of the pumps nor with the mechanical properties of their components.

This Standard contains two grades of accuracy of measurement: Grade 2 in normal test and Grade 1 for higher accuracy. For the pumps produced in series with selection made from typical performance curves and for pumps with a driver power input less than 10 kW, see Annex A for higher tolerance factors.

This 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.

Remarks: The international standard corresponding to this Standard is as follows.

ISO 9906 : 1999 *Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1 and 2*

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. If the indication of the year of publication is given to these referred standards, only the edition of indicated year constitutes the provisions of this Standard but the revision and amendment made thereafter are not applied. The normative references without the indication of the year of coming into effect apply limiting only to the most recent edition (including the amendment).

JIS B 7505 Bourdon tube pressure gauges

JIS B 7554 Electromagnetic flowmeters

Remarks: Cited matters from **ISO 9104: 1991** *Measurement of fluid flow in closed conduits — Methods of evaluating the performance of electromagnetic flow-meters for liquids* are equivalent to the corresponding matters in the said standard.

JIS B 8302 *Measurement methods of pump discharge*

Remarks: Clause **3** *Measurement by means of weirs* of this Standard is equivalent to the corresponding parts of **ISO 1438-1** Amendment 1: 1998 *Water flow measurement in open channels using weirs and venturi flumes — Part 1: Thin-plate weirs*.

JIS B 8327 *Testing methods for performance of pump, using model pump*

JIS C 1102-1 to 9 *Direct acting indicating analogue electrical measuring instruments and their accessories*

Remarks: These standards are identical with **IEC 60051-1 to 9**: 1984 *Direct acting indicating analogue electrical measuring instruments and their accessories — Part 1 to 9*.

JIS C 4207 *Calculating methods of three-phase induction motor characteristics*

Remarks: Cited matters from **IEC 60034-2**: 1972 *Rotating electrical machines — Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)* are equivalent to the corresponding matters of the said standard.

JIS Z 8762 *Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full*

Remarks: Cited matters from **ISO 5167-1**: 1991 *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* are equivalent to the corresponding matters in the said standard.

ISO 2186: 1973 *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*

ISO 3354: 1988 *Measurement of clean water flow in closed conduits — Velocity-area method using current-meters in full conduits and under regular flow conditions*

ISO 3966: 1977 *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

ISO 4373: 1995 *Measurement of liquid flow in open channels — Water level measuring devices*

ISO 5198: 1987 *Centrifugal, mixed flow and axial pumps — Code for hydraulic performance tests — Precision grade*

ISO 7194: 1983 *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: 1987 *Measurement of liquid flow in closed conduits — Method by collection of the liquid in a volumetric tank*

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

Table 1 shows the definitions of terms used in this Standard based on **JIS Z 8202**, and the related symbols allotted thereto. Table 2 shows the alphabetical list of symbols used, and Table 3 shows the list of subscripts. In this Standard, coherent SI units shall be used. For conversion of other units to SI units, see Annex D.

3.1 Terms, definitions, symbols and units The terms and their definitions shall follow Table 1.

Table 1 Terms, definitions, symbols and units

	Terms	Definitions	Symbols	Dimensions	Units
3.1.1	angular velocity	number of radians of a shaft per unit time. $\omega = 2\pi n$	ω	T ⁻¹	rad/s
3.1.2	acceleration due to gravity	(1)	g	LT ⁻²	m/s ²
3.1.3	speed of rotation	number of rotations per unit time	n	T ⁻¹	s ⁻¹
3.1.4	density	mass per unit volume	ρ	ML ⁻³	kg/m ³
3.1.5	pressure	force per unit area. In this 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.	p	ML ⁻¹ T ⁻²	Pa
3.1.6	power	energy transferred per unit time	P	ML ² T ⁻³	W
3.1.7	Reynolds number	Reynolds number shall be obtained by the following formula in this Standard. $Re = \frac{UD}{\nu}$	Re	dimensionless	
3.1.8	mass flow rate	mass passing per unit time which is discharged into the pipe from the outlet branch of the pump	q (2)	MT ⁻¹	kg/s
3.1.9	volume flow rate	The volume flow rate shall be obtained by the following formula. $Q = \frac{q}{\rho}$ However, if the compressibility of the pumped liquid is significant, the density ρ shall be replaced by the mean value: $\rho_m = \frac{\rho_1 + \rho_2}{2}$. The volume flow rate (4) at the designated section shall be designated by subscript. The volume flow rate is the value of the mass flow rate passing the section divided by the density at the section. Remarks 1 The following losses or abstractions are inherent to the pump and are not to be reckoned in the rate of flow: a) discharge necessary for hydraulic balancing of axial thrust b) cooling of bearings of the pump itself c) liquid seal to the packing 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 those shown below, may be reckoned in the rate of flow if abstractions are inherent to the upstream side of the section for measurement of the volume flow rate. - cooling of the motor bearings - cooling of a gear box (bearings, oil cooler), etc.	Q (3)	L ³ T ⁻¹	m ³ /s

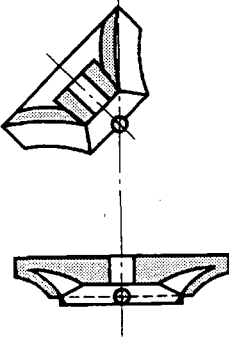
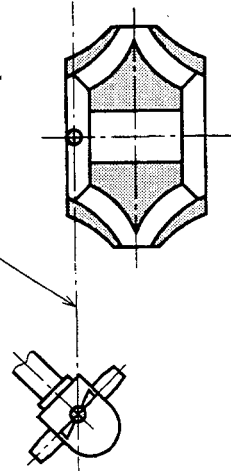
Table 1 Terms, definitions, symbols and units (continued)

	Terms	Definitions	Symbols	Dimensions	Units
3.1.10	mean velocity	mean axial velocity of flow equal to the volume flow rate divided by the pipe cross section area. $U = \frac{Q}{A}$	U	LT^{-1}	m/s
3.1.11	local velocity	local velocity of flow at any point	v	LT^{-1}	m/s
3.1.12	head	specific energy y (refer to 3.1.20), divided by acceleration due to gravity, g $\frac{y}{g}$		L	m
Notes (1) In the tests in Japan, it is sufficient to use the value of 9.80 m/s². The local value of g shall be as follows. $g = 9.7803 (1 + 0.0053 \sin^2 \psi) - 3 \cdot 10^{-6} Z$ where, ψ is the latitude (degree) and Z is the altitude (m). (2) An optional symbol for mass rate of flow is q_m. (3) An optional symbol for volume rate of flow is q_v. (4) In this case, attention shall be paid that the value of Q becomes different depending on the position.					
3.1.13	height above reference plane	height of the considered point above the reference plane Its value is: – positive, if the considered point is above the reference plane; – negative, if the considered point is below the reference plane. (Refer to Fig. 2 and Fig. 3.) reference plane: any horizontal plane used as a datum for height measurement For practical reasons it is preferable not to specify an imaginary reference plane. – difference between the NPSH reference plane (refer to 3.1.24) and the reference plane. pressure relative to atmospheric pressure Its value is: – positive, if this pressure is greater than the atmospheric pressure; – negative, if this pressure is less than the atmospheric pressure. kinetic energy per unit mass of the liquid in movement, divided by g : $\frac{U^2}{2g}$	z	L	m
3.1.14	gauge pressure		p	$ML^{-1}T^{-2}$	Pa
3.1.15	velocity head			L	m

Table 1 Terms, definitions, symbols and units (continued)

	Terms	Definitions	Symbols	Dimensions	Units
3.1.16	total head	in any section, the total head is given by: $H_x = z + \frac{p}{\rho g} + \frac{U^2}{2g}$ where, z : height of the center of the cross-section above the reference plane, and p : gauge pressure related to the center of the cross-section The absolute total head in any section is given by: $H_{x(\text{abs})} = z + \frac{p}{\rho g} + \frac{p_{\text{amb}}}{\rho g} + \frac{U^2}{2g}$		L	m
3.1.17	inlet total head	total head in the inlet section of the pump :	H_1	L	m
3.1.18	outlet total head	total head in the outlet section of the pump :	H_2	L	m
3.1.19	pump total head	$H = z_2 - z_1 + \frac{p_2 - p_1}{\rho g} + \frac{U_2^2 - U_1^2}{2g}$	H	L	m
3.1.20	specific energy (mass energy)	energy per unit mass of liquid	γ	$L^2 T^{-2}$	J/kg
3.1.21	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	H_{J1}	L	m
3.1.22	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	H_{J2}	L	m
3.1.23	pipe friction loss coefficient	coefficient for the head loss by friction in the pipe	λ	dimensionless	
3.1.24	NPSH	absolute inlet total head above the head equivalent to the vapor pressure relative to the NPSH datum plane: $NPSH = H_1 - z_D + \frac{p_{\text{amb}} - p_v}{\rho_1 g}$ This NPSH relates to the NPSH datum plane, whereas the inlet total head relates to the reference plane. NPSH datum plane: Horizontal plane through the center of the circle described by the external points of the entrance edges of the impeller blades. Plane through the higher center in the case of double inlet pumps with vertical or inclined axis. The manufacturer should indicate the position of this plane with respect to precise reference points on the pump.	NPSH	L	m

Table 1 Terms, definitions, symbols and units (concluded)

	Terms	Definitions	Symbols	Dimensions	Units
3.1.24.1	available NPSH, NPSHA		h_{sv}	L	m
3.1.24.2	required NPSH, NPSHR		H_{sv}	L	m
3.1.24.3	NPSH3	NPSH available as determined by the conditions of the installation for a specified flow rate	$NPSH3$	L	m
3.1.25	type number	minimum required NPSH given by the manufacturer/supplier for a pump to achieve a specified performance at a specified flow rate, speed and pumped liquid. For example, minimum NPSH necessary for preventing occurrence of visible cavitation, increase of noise and vibration due to cavitation, beginning of total head or efficiency drop, total head or efficiency drop of a given amount, limitation of cavitation erosion. 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	K	dimensionless	
		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' : volume rate of flow per eye, and H' : pump total head of the first stage Remarks: The type number is to be taken at maximum diameter of the first stage impeller.			
3.1.26	pump power input	power transmitted to the pump by its driver	P	ML^2T^{-3}	W
3.1.27	pump power output	mechanical power transferred to the liquid during its passage through the pump: $P_u = \rho Q g H = \rho Q y$	P_u	ML^2T^{-3}	W
3.1.28	driver power input	power absorbed by the pump driver	P_{gr}	ML^2T^{-3}	W
3.1.29	pump efficiency	$\eta = \frac{P_u}{P} = \text{pump power output / pump power input}$	η	dimensionless	
3.1.30	overall efficiency	$\eta_{gr} = \frac{P_u}{P_{gr}} = \text{pump power output / driver power input}$	η_{gr}	dimensionless	

3.2 Basic symbols and subscripts Basic symbols and subscripts shall be as specified in Table 2 and Table 3, respectively.

Table 2 Alphabetical list of basic letters used as symbols

Symbol	Quantity	Unit
<i>A</i>	Area	m ²
<i>D</i>	Diameter	m
<i>e</i>	Overall uncertainty, relative value	%
<i>E</i>	Energy	J
<i>f</i>	Frequency	s ⁻¹
<i>g</i>	Acceleration due to gravity	m/s ²
<i>H</i>	Pump total head	m
<i>H_J</i>	Losses in terms of head of liquid	m
<i>k</i>	Equivalent uniform roughness	m
<i>K</i>	Type number	(pure number)
<i>l</i>	Length	m
<i>m</i>	Mass	kg
<i>n</i>	Speed of rotation	s ⁻¹ , min ⁻¹
<i>NPSH</i>	Net positive suction head	m
<i>p</i>	Pressure	Pa
<i>P</i>	Power	W
<i>q</i>	Mass flow rate	kg/s
<i>Q</i>	Volume flow rate	m ³ /s
<i>R_e</i>	Reynolds number	(pure number)
<i>t</i>	Tolerance factor, relative value	%
<i>t</i>	Time	s
<i>T</i>	Torque	Nm
<i>U</i>	Mean velocity	m/s
<i>v</i>	Local velocity	m/s
<i>V</i>	Volume	m ³
<i>y</i>	Specific energy	J/kg
<i>z</i>	Height above reference plane	m
<i>z_D</i>	Difference between NPSH datum plane (see 3.25) and reference plane	m
<i>η</i>	Efficiency	(pure number)
<i>θ</i>	Temperature	°C
<i>λ</i>	Pipe friction loss coefficient	(pure number)
<i>ν</i>	Kinematic viscosity	m ² /s
<i>ρ</i>	Density	kg/m ³
<i>ω</i>	Angular velocity	rad/s

Table 3 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
gr	combined motor/pump unit (overall)
H	pump total head
m	mean
measured	measured
mot	driver
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 11 and Fig. 1), 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 defined in 6.4.1 and Fig. 1 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;

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 5.4.5.1)
- 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 Standard.

5 Execution of tests

5.1 Subjects of tests 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 a), b) and c) shall be agreed between the purchaser and manufacturer/supplier.

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 tests.

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

5.1.1 Contractual test — Fulfillment 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 Standard, the measured performance fails within the tolerance specified for the particular quantity (see 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.

5.1.2 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. Reference should be made to Annex 2 on the vibration, bearing temperature, hydraulic pressure resistance, and minimum volume flow rate during the test.

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

5.2.1 Location of tests

5.2.1.1 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.

5.2.1.2 Site tests Special agreement is necessary for performance tests on site providing all the requirements of this Standard can be satisfied. It is, however, recognised that the conditions at most sites often preclude full compliance with this 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.

5.2.2 Date of testing The date of testing shall be mutually agreed by the manufacturer/supplier and the purchaser.

5.2.3 Staff Accurate measurements depend not only on the quality of the measuring instruments used but also on the ability and skill of the persons operating and reading the measuring devices during the tests. The staff entrusted with effecting the measurements shall be selected just as carefully as the instruments to be used in the test.

Specialists with adequate experience in measuring operations in general shall be charged with operating and reading complicated measuring apparatus. Reading simple measuring devices may be entrusted to such helpers who (upon prior instruction) can be assumed to effect the readings with proper care and the accuracy required.

A test supervisor possessing adequate experience in measuring operations shall be mutually appointed. Normally, when the test is carried out at the manufacturer's works, the test supervisor is a staff member of the pump manufacturer.

During the tests all persons charged with effecting the measurements are subordinated to the chief of tests, who conducts and supervises the measurements, reports on test conditions and the results of the tests and then drafts the test report. All questions arising in connection with the measurements and their execution are subject to his decision.

The parties concerned shall provide all assistance that the chief of tests considers necessary.

5.2.4 State of pump When tests are not carried out in the manufacturer's works, opportunity shall be allowed for preliminary adjustments by both manufacture and installer.

5.2.5 Test programme The programme and procedure to be followed in the test shall be prepared by the test supervisor and submitted to both manufacturer/supplier and purchaser in ample time for consideration and agreement.

Only the guaranteed operational data (see 4.1) shall form the basis of the test, other data determined by measurement during the tests shall have merely an indicative (informative) function and it shall be so stated if they are included in the programme.

5.2.6 Testing equipment When deciding on the measuring procedure, the measuring and recording apparatus required shall be specified at the same time.

The test supervisor shall be responsible for checking the correct installation of the apparatus and its proper functioning.

All of the measuring apparatus shall be covered by reports showing by calibration or by comparison with other **JIS**, **ISO** or **IEC** standards that it complies with the requirement of 6.2. These reports shall be presented if required.

Guidance for suitable period between calibrations of test instruments is given in Annex E.

5.2.7 Records All test records and record charts shall be initialled by the test supervisor and by the representatives of both the manufacturer/supplier and purchaser if present, each of whom shall be provided with a copy of all records and charts.

The evaluation of the test results shall be made as far as possible while the tests are in progress and, in any case, before the installation and instrumentation are dismantled in order that suspect measurements can be repeated without delay.

5.2.8 Test report After scrutiny, the test results shall be summarized in a report which is signed by the test supervisor alone, or together, by him and representatives of the manufacturer/supplier and of the purchaser.

All parties specified in the contract shall receive a copy of the report.

The test report should contain the following information:

- a) place and date of acceptance test;

- b) manufacturer's name, type of pump, serial number, and possibly year of construction;
- c) impeller diameter, blade angle or other impeller identifications;
- d) guaranteed characteristics, operational conditions during the acceptance test;
- e) specification of the pump's driver;
- f) sketch of test arrangement, diameters of measuring sections, description of the test procedure and the measuring apparatus used including calibration data;
- g) readings;
- h) evaluation and analysis of test results;
- i) conclusions:
 - comparison of test results and the guaranteed quantities,
 - determination of action taken in connection with any special agreements that were made,
 - recommendation whether the pump can be accepted or should be rejected and under what conditions (if the guarantees are not fully satisfied the final decision whether the pump can be accepted or not is up to the purchaser).
 - statements arising out of action taken in connection with any special agreements that were made.

A pump test sheet is given for guidance in Annex J.

5.3 Test arrangements The conditions necessary to ensure satisfactory measurement of the characteristics of operation are defined in this subclause, taking into account the accuracy required for tests of grades 1 and 2.

- Remarks
- 1 The performance of a pump in a given test arrangement, however accurately measured, cannot be assumed to be a correspondingly accurate indication of its performance in another arrangement.
 - 2 Recommendations and general guidance about suitable pipe arrangements to ensure satisfactory measurements are given in 7 and 8 and, if necessary, they can be used in conjunction with JIS and ISO on measurement of flow rates in closed conduits concerning the different methods (see 7).

Annex 1 shows the informative reference figures of the test arrangements.

5.3.1 Standard test arrangements The best measuring conditions are obtained when, in the measuring sections, the flow has

- an axially symmetrical velocity distribution;
- a uniform static pressure distribution;
- freedom from swirl induced by the installation.

It is difficult to fully satisfy these conditions, but for practical purposes, the measurement may be made under the following conditions.

- a) Any bend or a combination of bends, any expansion or any discontinuity in the transverse profile in the vicinity of the measuring section shall be avoided.

- b) For standard test arrangements leading from reservoirs with a free surface or from large stilling vessels in a closed circuit, the inlet straight length L shall be determined by the following expressions (where, D is the pipe diameter).

For the tests of grade 1 : $L/D \geq K + 5$

For the tests of grade 2 : $L/D \geq 4$

Under these conditions, flow straighteners are not necessary in the pipe between the bend and the pump. However, in a closed circuit where there is neither a reservoir nor a stilling vessel immediately upstream of the pump, flow straighteners are necessary.

- c) It is recommended not to install a throttle valve in the suction pipe (see 5.4.4). If this cannot be avoided, for instance for cavitation tests, the straight pipe length between the valve and the pump inlet should be in conformity with the requirements of 11.2.1.

5.3.1A Pump performance test by model In the following cases, the pump performance test may be replaced by the test using a model pump subjected to the agreement (see JIS B 8327).

- a) when no performance test can be carried out in the works because the pump is large in volume flow rate or power.
- b) when part of the pump-casing forms a structure of concrete, etc., and a complete assembly is impossible in the works.

5.3.2 Simulated test arrangements When it is agreed to test a pump under simulated site conditions, it is important that at the inlet of the simulated circuit the flow should as far as possible be free from significant swirl induced by the installation and have a symmetrical velocity distribution. All necessary provisions shall be made to ensure these conditions are achieved.

If necessary, for grade 1 tests the velocity distribution of the flow into the simulated circuit shall be determined by careful Pitot tube traverses, in order to establish that the required flow characteristics exist. If not, the required characteristics can be obtained by the installation of suitable means, such as a flow straightener, adapted to correct the fault in the flow (swirl or asymmetry). Specifications of the most widely used types of flow straighteners can be found in ISO 7194. But care shall be taken to ensure that the conditions of test will not be affected by the pressure losses associated with some straightening devices.

5.3.3 Pumps tested with fittings If specified in the contract, standard tests can be carried out on a combination of a pump and the following:

- a) associated fittings at the final site installation; or
- b) an exact reproduction thereof; or
- c) fittings introduced for testing purposes and taken as forming part of the pump itself.

The flow at the inlet and outlet of the whole combination shall comply with the requirements specified in 5.3.1. Measurements shall be taken in accordance with 8.2.2.

5.3.4 Pumping installation under submerged conditions Where a pump, or a combination of a pump and its fittings, is tested or installed in conditions where the standard pipe connection as described in 5.3.1 cannot be made owing to inaccessibility or submergence, measurements shall be taken in accordance with 8.2.3.

5.3.5 Borehole and deep-well pumps Borehole and deep-well pumps cannot usually be tested with their complete lengths of delivery main and, consequently, the loss of head in the portions omitted and the power absorbed by any shafting therein, cannot be taken into account. The thrust bearing will be more lightly loaded during the test than it would be in the final installation. The measurements shall be taken in accordance with 8.2.3.

5.3.6 Self-priming pumps In principle, the priming ability of self-priming pumps shall always be verified at the contractual static suction head with the attached inlet piping equivalent to that in the final installation. When the test cannot be carried out in the described manner, the test arrangement to be used shall be specified in the contract.

Annex 3 shows the informative self-priming ability test method of self-priming pumps.

5.4 Test conditions

5.4.1 Test procedure The duration of the test shall be sufficient to obtain consistent results regarding the degree of accuracy to be achieved.

All measurements shall be made under steady conditions of operation or unsteady within the limits given in Table 5.

A decision to make measurements when such conditions cannot be obtained shall be a matter of agreement between the parties concerned.

Verification of the guarantee point shall be obtained by recording at least three (grade 2 tests) or five (grade 1 tests) points of measurements closely and evenly grouped around the guarantee point, for example between $0.9 Q_G$ and $1.1 Q_G$.

Where, for special reasons, it is necessary to determine performance over a range of operating conditions, a sufficient number of measurement points shall be taken to establish the performance within the limits of uncertainty stated in 6.2.

Informative reference: The informative number of measurement points is shown below when the pump ability curve is obtained in a certain range.

- a) For the test of centrifugal pumps, measurements should be made for at least 5 kinds of different volume flow rates ranging from that in the vicinity of the closing point to the volume flow rate as large as possible, and at least one kind should be measured at the head lower than the specified value.
- b) For the test of mixed flow pumps, measurements should be made for at least 5 kinds of different volume flow rates above and below the specified head ranging from the volume flow rate as large as possible to the volume flow rate as small as possible.

- c) For the test of axial flow pumps, measurements should be made for at least 5 kinds of different volume flow rates ranging from that in the open point to the volume flow rate as small as possible, and at least one kind should be measured at the head higher than the specified value.

If the driving power available during a test on a test stand is insufficient, and if the test has to be carried out at reduced speed of rotation, the test results shall be translated to the specified speed of rotation in accordance with 6.1.1.

5.4.2 Stability of operation

5.4.2.1 General remarks For the purposes of this Standard, the following shall be considered.

- a) Fluctuations: short-period changes in the measured value of a physical quantity about its mean value during the time that a single reading is being made.
- b) Variations: those changes in value which take place between one reading and the next.

5.4.2.2 Permissible fluctuations in readings and use of damping

5.4.2.2.1 Direct visual observation of the signals delivered by measuring systems For each quantity to be measured, Table 4 gives the permissible amplitude of fluctuations.

Where the construction 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 4.

Since it is possible that damping will significantly affect the accuracy of the readings, use shall be made of symmetrical and linear damping device, for example a capillary tube, which has to provide an integration over at least one complete cycle of fluctuations.

Table 4 Permissible amplitude of fluctuations as a percentage of mean value of quantity being measured

Unit: %

Measured quantity	Permissible amplitude of fluctuations	
	Grade 1	Grade 2
Flow rate Pump total head Torque Power input	± 3	± 6
Speed of rotation	± 1	± 2
When using a differential pressure device to measure flow rate, the permissible amplitude of the fluctuations of the observed differential pressure shall be ± 6 % for grade 1 and ± 12 % for grade 2. In the case of separate measurements of inlet total pressure and outlet total pressure, the maximum permissible amplitude of fluctuation shall be calculated on the pump total head.		

5.4.2.2.2 Automatic recording or integration of signals delivered by measuring systems When the signals delivered by the measuring systems are automatically recorded or integrated by the measuring device, the maximum permissible fluctuation amplitude of these signals may be higher than the value given in Table 4, if

- a) the measuring system used includes an integrating device carrying out automatically, with the required accuracy, the integration necessary to calculate the mean value over an integration period much longer than the response time of the corresponding systems;
- b) the integration necessary to calculate the mean value may be carried out later on, from the continuous or sampled record of the analog signal $x(t)$. (The sampling conditions should be specified in the test report.)

5.4.2.3 Number of sets of observations

5.4.2.3.1 Steady conditions Test conditions are called steady if the mean value of all quantities involved (rate of flow, pump total head, power input, torque and speed of rotation) are independent of time. In practice, test conditions may be regarded as steady if the variations of each quantity, observed at the test operating point for at least 10 s, do not exceed the values given in the upper part of Table 5. If this condition is met, and if the fluctuations are less than the permissible values given in Table 4, only one set of readings of individual quantities will be recorded for the test point considered.

5.4.2.3.2 Unsteady conditions In such cases where the unsteadiness of test conditions gives rise to doubts concerning the accuracy of the tests, the following procedure shall be followed.

At each test point repeated readings of the measured quantities shall be made at random intervals of time, but not less than 10 s, only speed of rotation and temperature being allowed to be controlled. All settings of the throttle valve, water level, gland, balance water, etc. shall be left completely unaltered.

The difference between these repeated readings of the same quantities will be a measure of the unsteadiness of the test conditions, which are at least partly influenced by the pump under test as well as by the installation.

A minimum of three sets of readings shall be taken at each test point, and the value of each separate reading and of the efficiency derived from each set of readings shall be recorded. The percentage difference between the largest and smallest values of each quantity shall not be greater than that given in Table 5. It should be noted that a wider difference is permitted if the number of readings is increased (see Table 5).

**Table 5 Limits of variations between repeated measurements
of the same quantity
(based on 95 % confidence limits)**

Unit: %

Conditions	Number of sets of readings	Permissible difference between largest and smallest readings of each quantity, related to the mean value			
		Flow rate, pump total head, torque, power input		Speed of rotation	
		grade 1	grade 2	grade 1	grade 2
Steady	1	0.6	1.2	0.2	0.4
Unsteady	3	0.8	1.8	0.3	0.6
	5	1.6	3.5	0.5	1.0
	7	2.2	4.5	0.7	1.4
	9	2.8	5.8	0.8	1.6
	13	2.9	5.9	0.9	1.8
	> 20	3.0	6.0	1.0	2.0

These maximum permissible differences are designed to ensure that the uncertainties due to scatter, taken together with the systematic uncertainties given in Table 8, will result in overall measurement uncertainties not greater than those given in Table 9.

The arithmetic mean of all the readings for each quantity shall be taken as the actual value for the purposes of the test.

If the values given in Table 5 cannot be reached, the cause shall be ascertained, the conditions rectified and a new complete set of readings made, i.e. all the readings in the original set shall be rejected. No reading or selection of readings in the set of observations may be rejected because it lies outside the limits.

In the case where the excessive variation is not due to procedure or instrumentation errors, and cannot therefore be eliminated, the limits of error may be calculated by statistical analysis.

5.4.3 Speed of rotation during test Unless otherwise agreed, tests may be carried out at a test speed of rotation within the range 50 % to 120 % of the specified speed of rotation to establish the flow rate, pump total head and power input. However, it should be noted that when departing by more than 20 % from the specified speed of rotation the efficiency may be affected.

For NPSH tests, the test speed of rotation should lie within the range 80 % to 120 % of the specified speed of rotation, provided that the rate of flow lies within 50 % and 120 % of the rate of flow corresponding to the maximum efficiency at the test speed of rotation.

Remarks: For tests conforming to the requirements of 11.1.2.1 and 11.1.2.2, the above-mentioned variation may always be allowed. For tests conforming to the requirements of 11.1.2.3, it may be allowed for pumps with type number *K* less than or equal to 2; for pumps with type number *K* greater than 2, agreement should be reached between the parties concerned.

5.4.4 Setting pump total head The test conditions may be obtained, among other methods, by throttling in either or both the inlet and outlet pipes. (In the standard practice, the discharge valve of the outlet pipe should be throttled.) When throttling in the inlet pipe is used, due consideration shall be given to the possibility of cavitation or of air coming out of the water, which might affect the operation of the pump, the flow measuring device or both (see 11.2.1).

5.4.5 Test on pumps for liquids other than clean cold water 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 on another liquid, it is often desirable for the parties to agree on empirical rules to suit the particular circumstances and test the pump with clean cold water.

Annexes G and H may be considered as a guide.

5.4.5.1 Characteristics of clean cold water The characteristics of the water corresponding to what is called in this Standard "clean cold water" shall be within the limits indicated in Table 6.

Table 6 Specification of clean cold water

Characteristics	Unit	max.
Temperature	°C	40
Kinematic viscosity	m ² /s	1.75×10^{-6}
Density	kg/m ³	1 050
Non-absorbent free solid content	kg/m ³	2.5
Dissolved solid content	kg/m ³	50

The total dissolved and free gas content of the water shall not exceed the saturation volume corresponding

- for an open circuit, to the pressure and temperature in the pump sump;
- for a closed loop, to those existing in the tank.

5.4.5.2 Characteristics of liquids for which clean cold water tests are acceptable Pumps for liquids other than clean cold water may be tested for head and for flow rate and efficiency with clean cold water if the liquid is within the specifications in Table 7.

Table 7 Characteristics of liquids

Characteristics	Unit	min.	max.
Kinematic viscosity	m ² /s	no limit	10×10^{-6}
Density	kg/m ³	450	2 000
Non-absorbent free solids contents	kg/m ³	—	5.0

The total dissolved and free gas content of the liquid shall not exceed the saturation volume corresponding

- for an open circuit, to the pressure and temperature in the pump sump;
- for a closed loop, to those existing in the tank.

Tests on pumps for liquids other than those specified above shall be subject to special agreement.

In the absence of a special agreement, cavitation tests shall be carried out with clean cold water. Attention is drawn to the fact that the results may be affected by this procedure when the liquid to be pumped is not clean cold water ⁽¹⁾.

Note ⁽¹⁾ The usual NPSHR curves of pump manufacturers are established using clean cold water and the NPSHR values are always given for clean cold water.

6 Analysis of test results

6.1 Translation of the test results to the guarantee conditions In order to determine whether the guarantee would have been fulfilled if the tests had been conducted under the guarantee conditions, it is necessary to translate the quantities measured under different conditions to those measured under guarantee conditions.

6.1.1 Translation of the test results into data based on the specified speed of rotation (or frequency) and density All test data obtained at the speed of rotation n in deviation from the specified speed of rotation n_{SP} shall be translated to the basis of the specified speed of rotation n_{SP} .

If the deviation from the test speed of rotation n to the specified speed of rotation n_{SP} does not exceed the permissible variations stated in 5.4.3 and if the deviation of the test liquid from the specified liquid is within the limits stated in 5.4.5.2, the measured data on the rate of flow Q , the pump total head H , the power input P , and the pump efficiency η can be converted by means of the equations:

$$Q_T = Q \frac{n_{SP}}{n}$$

$$H_T = H \left(\frac{n_{SP}}{n} \right)^2$$

$$P_T = P \left(\frac{n_{SP}}{n} \right)^3 \cdot \frac{\rho_{SP}}{\rho}$$

$$\eta_T = \eta$$

and the results obtained for the NPSHR can be converted by means of the equation.

$$H_{SVT} = H_{SV} \left(\frac{n_{SP}}{n} \right)^x$$

The value $x = 2$ may be used if the specified conditions given in 5.4.3 for the speed of rotation and the rate of flow have been fulfilled and if the physical state of the liquid at the impeller inlet is such that no gas separation can affect the operation of the pump ⁽²⁾.