INTERNATIONAL STANDARD ISO 2548

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Centrifugal, mixed flow and axial pumps — Code for acceptance tests — Class C

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2548 was drawn up by Technical Committee ISO/TC 115, *Pumps*, and circulated to the Member Bodies in November 1971.

It has been approved by the Member Bodies of the following countries :

Austria	Israel	South Africa, Rep. of
Belgium	Italy	Spain
Czechoslovakia	Japan	Sweden
Egypt, Arab Rep. of	Netherlands	Switzerland
France	New Zealand	Thailand
Germany	Norway	Turkey
Hungary	Poland	United Kingdom
India	Portugal	USSR
Ireland	Romania	

The Member Body of the following country expressed disapproval of the document on technical grounds :

Australia

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Centrifugal, mixed flow and axial pumps – Code for acceptance tests – Class C

WARNING – Terms used in this International Standard like "guarantee" or "acceptance" must 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.

0 INTRODUCTION

This International Standard is the first of a set dealing with acceptance tests of centrifugal, mixed flow and axial pumps[1]; they correspond to three classes of tests A, B and C : class A is the most accurate and class C is the least accurate; the use of classes A and B is restricted to special cases when there is a need to have the pump performance more precisely defined.

Attention is drawn to the fact that class B and A tests require more accurate apparatus and methods, which increases the cost of such tests.

The standard arrangements and procedures described are those to be employed for testing a pump individually, without reference to its final installation conditions or the effect upon it of any associated fittings, these being the usual conditions in which a pump is tested at the manufacturer's works.

Pump performance may be affected by conditions of the final site installation, and procedures are described for carrying out "standard tests" on certain types of installations of which an overall performance is required.

The conditions in which pumps are finally installed, however, often do not permit reliable test measurements, and recommendations are made concerning the procedure to be adopted where the layout precludes tests in conformity with the standards, or where the tests cover the pump and the plant ancillary to the pump itself.

In this test code, all formulae are given in coherent units.

1 SCOPE AND FIELD OF APPLICATION

This International Standard constitutes a code for acceptance testing of pumps, defining the terms and quantities that are used, establishing the methods of testing and the ways of measuring the quantities involved according to class C so as to ascertain the performances of the pump and to compare them with the manufacturer's guarantee.

In general this code applies to any sizes of pumps tested with clean cold water and other liquids behaving as clean cold water such as defined in section 8.

This code is not concerned with the structural details of the pumps nor with the mechanical properties of their components.

1) In the rest of the text these three types of pumps will be simply designated as "pumps".

2 SYMBOLS

2.1 List of symbols used in the test code

TABLE 1 — **Symbols**

Reference number in ISO/R 31[1)]	Reference number in ISO 2548	Quantity	Symbol	Dimensions[2)]	SI units
3.1.1		Mass	m	M	kg
1.3.1		Length	l	L	m
1.6.1		Time	t	T	s
4.2.1		Temperature	θ	Θ	°C
1.4.1		Area	A	L^2	m^2
1.5.1		Volume	V	L^3	m^3
1.8.1		Angular velocity	ω	T^{-1}	rad/s
1.10.1		Velocity	v	LT^{-1}	m/s
1.11.2		Acceleration of free fall	g	LT^{-2}	m/s^2
2.3.2		Speed of rotation	n	T^{-1}	s^{-1}
3.2.1		Density	ρ	ML^{-3}	kg/m^3
3.11.1		Pressure	p	$ML^{-1}T^{-2}$	N/m^2 6)
3.19.1		Viscosity (dynamic viscosity)	μ	$ML^{-1}T^{-1}$	$N{\cdot}s/m^2$
3.20.1		Kinematic viscosity	ν	L^2T^{-1}	m^2/s
3.22.2		Energy	E	ML^2T^{-2}	J
3.23.1		Power (general term)	P	ML^2T^{-3}	W
12.1		Reynolds number	Re	pure number	
		Diameter	D	L	m
	3.2.1.1	Mass rate of flow	q 3)	MT^{-1}	kg/s
	3.2.1.2	Volume rate of flow	Q 4)	L^3T^{-1}	m^3/s
	3.2.3.2	Distance to reference plane	z	L	m
	3.2.3.8	Pump total head	H	L	m
	3.2.3.6	Inlet total head	H_1	L	m
	3.2.3.7	Outlet total head	H_2	L	m
	3.2.3.9	Specific energy	Y	L^2T^{-2}	J/kg
	3.2.3.10	Loss of head at inlet	H_{J1}	L	m
	3.2.3.11	Loss of head at inlet	H_{J2}	L	m
	3.2.3.12	Net positive suction head	(NPSH) 5)	L	m
		Atmospheric pressure (absolute)	p_b	$ML^{-1}T^{-2}$	N/m^2 6)
		Vapour pressure (absolute)	p_v	$ML^{-1}T^{-2}$	N/m^2 6)
	3.2.4.2	Pump power input	P	ML^2T^{-3}	W
	3.2.4.1	Pump power output	P_u	ML^2T^{-3}	W
	3.2.4.3	Motor power input	P_{gr}	ML^2T^{-3}	W
	3.2.5.1	Pump efficiency	η	pure number	
	3.2.5.2	Transmission efficiency	η_{int}	pure number	
	3.5.2.3	Motor efficiency	η_{mot}	pure number	
	3.2.5.4	Overall efficiency	η_{gr}	pure number	
	3.2.6	Type number	K	pure number	
	5.7.6	Friction factor	λ	pure number	

1) ISO/R 31 (See Appendix W.)

2) M = Mass L = Length T = Time Θ = Temperature.

3) An optional symbol for mass rate of flow is q_m.

4) An optional symbol for volume rate of flow is q_v.

5) An optional symbol for net positive suction head is H_H.

6) Also called pascal (symbol Pa).

2.2 Alphabetical lists of basic letters and subscripts

TABLE 2 — **Letters used as symbols**

Symbol	Quantity	SI units
A	Area	m^2
D	Diameter	m
E	Energy	J
g	Acceleration of free fall	m/s^2
H	Head	m
H_J	Losses in terms of head of liquid	m
K	Type number	pure number
l	Length	m
m	Mass	kg
n	Speed of rotation	s^{-1}
(NPSH)	Net positive suction head	m
p	Pressure	N/m^2
P	Power	W
q	Mass rate of flow	kg/s
Q	Volume rate of flow	m^3/s
Re	Reynolds number	pure number
t	Time	s
v	Velocity	m/s
V	Volume	m^3
Y	Specific energy	J/kg
z	Distance to reference plane	m
η	Efficiency	pure number
θ	Temperature	°C
μ	Dynamic viscosity	$N{\cdot}s/m^2$
ν	Kinematic viscosity	m^2/s
ρ	Density	kg/m^3
ω	Angular velocity	rad/s
λ	Friction factor	pure number

TABLE 3 — **Letters and figures used as subscripts**

Subscript	Meaning
1	inlet
2	outlet
a	available
b	atmospheric
G	guaranteed
gr	unit (overall)
int	intermediate
M	manometric
mot	motor
P	pump
r	required
S	eye
sp	specified[1]
t	total
u	useful
v	vapour (pressure)

3 DEFINITIONS

3.1 GENERAL DEFINITIONS

In order to avoid any error of interpretation it has seemed preferable to reproduce here the definitions of quantities and units as given in ISO/R 31 and to supplement these definitions by some specific information on their use in this test code.

g — **acceleration of free fall**[2]

n — **speed of rotation** : The quotient of the number of rotations by the time.

ρ — **density** : The quotient of mass by volume.

p — **pressure** : The quotient of force by area. Unless otherwise specified, all pressures are gauge pressures, i.e. measured with respect to the atmospheric pressure.

μ — **viscosity** (dynamic viscosity, sometimes called absolute viscosity) is defined by the expression :

$$\tau = \mu \frac{u_o}{h}$$

where

u_o is the velocity of a flat plate moving in its own plane while keeping parallel to a fixed flat wall;

h is the distance from the flat plate to the fixed flat wall;

τ is the friction force of the fluid on the area unit of the flat plate during its motion.

NOTE — h should be small enough to obtain laminar flow of the fluid between the flat plate and the fixed flat wall.

ν — **kinematic viscosity** : The quotient of the viscosity (dynamic viscosity) by the density :

$$\nu = \frac{\mu}{\rho}$$

P — **power** : The quotient of the energy transferred during a time interval by the duration of this interval.

Re — **Reynolds number** is defined by the expression :

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

3.2 DEFINITIONS PECULIAR TO THE TEST CODE

This clause gives the definitions of concepts used in this test code, together with the associated symbols, if any have been allocated.

Concepts, even though in current use, which are not strictly necessary to the application of this code are not here defined.

1) This indication applies to the values of quantities relating to the guarantee point.

2) For Class C test the value of g is assumed to be 9,81 m/s^2.

3.2.1 Flow rates

3.2.1.1 q – In this test code, the **mass rate of flow** designates the external mass rate of flow of the pump, i.e. the rate of flow discharged into the pipe from the outlet branch of the pump.

NOTE – Losses or abstractions inherent to the pump i.e. :

a) discharge necessary for hydraulic balancing of axial thrust,

b) cooling of bearings of the pump itself,

c) water seal to the packing,

d) leakage from the fittings, internal leakage, etc.,

are not to be reckoned in the quantity delivered. On the contrary, if they are taken at a point before the flow measuring section, all derived quantities used for other purposes, such as :

e) cooling of the motor bearings,

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

should be added to the measured rate of flow.

3.2.1.2 Q – The **outlet volume rate of flow** has the following value :

$$Q = \frac{q}{\rho_2}$$

In this test code, this symbol may also designate the **volume rate of flow in a given section**[1]; it is the quotient of the mass rate of flow in this section by the density. (The section may be designated by the proposed subscripts.)

3.2.2 v – **velocity of flow** : The mean velocity of flow equal to the volume rate of flow divided by the pipe cross-section[1] :

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

3.2.3 head : The energy per unit weight of fluid.

3.2.3.1 reference plane : The horizontal plane through the centre of the circle described by the external point of the entrance edges of the impeller blades; in the case of double inlet pumps the plane should be taken through the higher centre.

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

3.2.3.2 z designates the difference between the level of the horizontal plane under consideration and the level of the reference plane. Its value is

– positive, if the plane in question is above the reference plane;

– negative, if the plane in question is below the reference plane.

3.2.3.3 p – **gauge pressure** : The effective pressure, relative to atmospheric pressure. The head corresponding to this pressure is

$$\frac{p}{\rho g}$$

Its value is

– positive if this pressure is greater than the atmospheric pressure;

– negative if this pressure is less than the atmospheric pressure.

3.2.3.4 dynamic head : The kinetic energy per unit weight of the liquid in movement. It is expressed by :

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

where v is the mean velocity of the liquid in the section considered.

3.2.3.5 total head : In any section, the total head is given by :

$$z + \frac{p}{\rho g} + \frac{v^2}{2g}$$

This is related to atmosphere. The absolute total head in any section is given by :

$$z + \frac{p}{\rho g} + \frac{p_b}{\rho g} + \frac{v^2}{2g}$$

3.2.3.6 H_1 – **inlet total head** : The total head in the inlet section of the pump :

$$H_1 = z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g}$$

3.2.3.7 H_2 – **outlet total head** : The total head in the outlet section of the pump :

$$H_2 = z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g}$$

3.2.3.8 H – **pump total head** : The algebraic difference between the outlet total head, and the inlet total head.

$$H = H_2 - H_1$$

$$= z_2 - z_1 + \frac{p_2 - p_1}{\rho g} + \frac{v_2^2 - v_1^2}{2g}$$

If the compressibility of the pumped liquid is significant, ρ may be replaced by the mean value

$$\rho_m = \frac{\rho_1 + \rho_2}{2}$$

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

3.2.3.9 Y – **specific energy :** The energy per unit mass of liquid. It is given by the equation

$$Y = gH$$

3.2.3.10 H_{J1} – **loss of total head at inlet :** The difference between the total head of the liquid at the measuring point, or possibly of the liquid without velocity in the suction chamber, and the total head of the liquid in the inlet section of the pump.

3.2.3.11 H_{J2} – **loss of total head on delivery :** The 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.

3.2.3.12 (NPSH) – **net positive suction head :** The total inlet head, plus the head corresponding to the atmospheric pressure, minus the head corresponding to the vapour pressure :

$$(\text{NPSH}) = H_1 + \frac{p_b}{\rho g} - \frac{p_v}{\rho g}$$

Thus (NPSH), as well as inlet total head, is referred to the reference plane.

It is necessary to make a distinction between

– the (NPSH) *required* at given flow and speed of rotation for a given pump; it is specified by the manufacturer;

– the (NPSH) *available* for the same flow which is inferred from the installation;

– the *test* (NPSH) – see 7.1.1.

Subscripts may be used to differentiate these quantities (for example $(\text{NPSH})_r$ when the required value is concerned and $(\text{NPSH})_a$ when the available value is concerned).

3.2.4 Power

3.2.4.1 P_u – **pump power output :** The power transferred to the liquid at its passage through the pump :

$$P_u = \rho g H = \rho Y$$

3.2.4.2 P – **pump power input :** The power measured at the pump coupling.

3.2.4.3 P_{gr} – **motor power input :** The power absorbed by the pump driver.

3.2.5 Efficiency

3.2.5.1 η – **pump efficiency :**

$$\eta = \frac{P_u}{P} = \frac{\text{Pump power output}}{\text{Pump power input}}$$

3.2.5.2 η_{int} – **transmission efficiency** (shafting, coupling, gears, etc.) :

$$\eta_{int} = \frac{\text{Pump power input}}{\text{Power at motor shaft}}$$

3.2.5.3 η_{mot} – **motor efficiency :**

$$\eta_{mot} = \frac{\text{Power at motor shaft}}{\text{Motor power input}}$$

3.2.5.4 η_{gr} – **overall efficiency :**

$$\eta_{gr} = \eta \, \eta_{int} \, \eta_{mot} = \frac{\text{Pump power output}}{\text{Motor power input}}$$

3.2.6 Type number K

The type number, a dimensionless quantity, is defined by the following formula[1] :

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

NOTE – Attention is drawn to the fact that in this International Standard, the type number is based on the total head of a multistage pump, and not on the head per stage, and that it applies to the guaranteed flow rate, which is not in conformity with the common practice where K is calculated for the flow rate corresponding to the maximum efficiency.

4 GUARANTEES AND PURPOSE OF THE TESTS

4.1 Guarantees

4.1.1 *Subjects of guarantees*

It shall be agreed in the contract which values are guaranteed by the manufacturer and under what conditions.

One or more of the following quantities are usually guaranteed :

– outlet rate of flow of pump

– total head of pump

– power input or efficiency of pump or combined motor-pump unit (for example submersible pump or monobloc pump; or separate pump and motor with overall efficiency guaranteed)

– (NPSH).

Whichever of these quantities is guaranteed, it is necessary to specify the speed of rotation (or in some cases the electrical supply frequency and voltage for the motor-pump unit) and the chemical and physical properties of the liquid to be pumped (if other than clean cold water).

1) This formula is the same as the basic formula $K = \frac{\omega Q^{1/2}}{Y^{3/4}}$

It is recommended that in national standards based on this International Standard practical equations for the commonly used units should be given in addition to the homogeneous equations given above.

In this test code the guarantees only refer to the pump including the test arrangements as given in 5.7. In particular, the guarantees do not apply to

— the test of the pipe and its fittings, such as valves, etc.,

— the general installation *in situ*,

if these parts do not belong to the test arrangements according to 5.7.

The pump manufacturer is responsible neither for the determination of the pump guarantee point, nor for the arrangement of the pump, nor for the installation *in situ*, the sole exception being when he has undertaken these tasks as part of the order.

4.1.2 *Extent of guarantees*

The guarantee of the flow rate covers the flow rate at the agreed total head and speed of rotation, within the permissible tolerances above and below as given by 9.4.1.

The guarantee of the head covers the pump total head (H) at the agreed flow rate and speed of rotation, within the permissible tolerances above and below as given by 9.4.1.

The guarantee of the efficiency covers the minimum value of efficiency at the guaranteed point QH within the permissible tolerances as given by 9.4.2.

If the flow rate values and the efficiency stated are not guaranteed but are indicated on the basis of prior tests or are given in printed curves (for mass produced pumps) see Annex B.

For a combined motor-pump unit (for example submersible pump or monobloc pump; or separate pump and motor with overall efficiency guaranteed) the guarantee covers the efficiency of the entire unit.

4.1.3 *Implementation of guarantees*

4.1.3.1 FLOW RATE AND TOTAL HEAD VALUES

The guarantee for flow rate and total head is fulfilled if, at the agreed speed of rotation, the value of the equation given in 9.4.1 is greater than or equal to 1.

4.1.3.2 EFFICIENCY

The efficiency guarantee is fulfilled if, at the agreed speed of rotation, the conditions given in 9.4.2 have been achieved or exceeded.

4.1.3.3 NET POSITIVE SUCTION HEAD (NPSH)

When a test of (NPSH) is specified in the contract, the guarantees as defined in 4.1.3.1 and 4.1.3.2 shall be achieved under those conditions of (NPSH) that are specified. This does not necessarily ensure absence of cavitation (see section 7).

4.1.3.4 MOTOR SPEED OF ROTATION

If the driving motor is being supplied by the pump manufacturer, the speed of rotation named in 4.1.2 and 4.1.3 can be replaced by the frequency and the voltage.

4.2 Purpose of the tests

4.2.1 *Contractual object of the tests*

The tests are intended to ascertain the performance of the pump and to compare this with the manufacturer's guarantee. When (NPSH) also is to be guaranteed, it shall be specified in the contract whether (NPSH) is to be tested or not. Attention is drawn to the fact that a test of (NPSH) increases the costs of the tests. (See also Appendix V.)

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

4.2.2 *Range of performance test*

The performance test of the pump shall be carried out to determine the performance of the pump with respect of the discharged rate of flow, total head, power absorbed, etc.

A check of the satisfactory running of the pump may be made from the point of view of cavitation, temperature of glands and bearings, axial thrust, and possible air or water leakage, provided the hydraulic test is carried out at the specified speed of rotation.

NOTE — It is also possible to observe the amount of noise and vibration and if necessary to examine this in the light of ISO publications.

4.2.3 *Liquid used in testing*

The liquid used in testing shall be clean cold water in accordance with the recommendations of section 8, unless otherwise specified in the contract.

5 ORGANIZATION OF TESTS

5.1 Place of testing

Acceptance tests shall be carried out either at the manufacturer's works, or alternatively at a place to be mutually agreed between the manufacturer and the purchaser.

5.2 Time of testing

The time of testing shall be mutually agreed by the manufacturer and the purchaser.

When tests are not carried out in the manufacturer's works, time should be allowed for preliminary adjustments by both the manufacturer and the installer.

5.3 Test validity

It should be ascertained that conditions permit tests to be made in accordance with the provisions of this code.

5.4 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 must 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 short prior instruction – can be assumed to effect the readings with proper care and the accuracy required.

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

All persons charged with effecting the measurements are subordinated during the tests 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.

5.5 Test programme

Only the guaranteed operational data 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.

5.6 Testing apparatus

When the measuring procedure is being decided on, the measuring and recording apparatus required shall be specified at the same time.

The chief of tests shall be responsible for checking the correct installation of these apparatuses and their perfect functioning.

All of the measuring apparatus shall be covered by reports showing by calibration or by comparison with other ISO documents that it complies with the requirements of 5.12. These reports shall be presented if required.

5.7 Test arrangements

5.7.1 *Standard test arrangements*

Ideally, the flow through the inlet head measuring section should be such that

a) the velocity is uniform, and axial, across the section;

b) the static pressure across the section is uniform.

These are the conditions for the standard test arrangement, but they are impossible to achieve completely, and it is impracticable to check them for the class of test covered by this International Standard.

However, significant maldistribution and swirl can be avoided by keeping bends and combinations of bends, and divergences and discontinuities of cross-sectional area, from the proximity of the measuring section. In general, the importance of inlet flow conditions increases with the pump type number, and for type numbers greater than 1,5 it is more meaningful to reproduce site conditions than it is to use a standard test arrangement. For such non-standard conditions an agreement shall be reached in the contract.

5.7.1.1 INLET PRESSURE TAPPINGS

In general, the pressure tapping shall be placed in a section of equal diameter to, and concentric with, the inlet branch of the pump. It should under normal conditions be located two diameters upstream from the pump inlet flange. Moreover it shall never be placed

a) in a diverging section, or within four diameters of straight pipe downstream from the divergence;

b) within the plane of a bend, either in the bend itself or within four diameters of straight pipe downstream from the bend. It may, however, be agreed to site a pressure tapping in this region at right angles to the plane of the bend;

c) within four diameters of straight pipe following a sudden contraction, or other discontinuity of cross-sectional area.

When interpretation of readings in non-standard conditions is being negotiated, consideration shall be given to

a) whether the value of inlet head itself is important (for example for NPSH tests);

b) the ratio of inlet velocity head to the pump total head.

If this ratio is very small (less than 0,5 %) and the value of inlet head itself is not important, readings from a tapping in the pump inlet flange may be used in the inlet total head equation given in 3.2.3.6 (for ratio $>$ 0,5 % : 2 *D* upstream).

5.7.1.2 OUTLET PRESSURE TAPPINGS

Under normal conditions the outlet pressure tapping should be located two diameters downstream from the pump outlet flange.

For the pumps of type number equal to or less than 0,5, the outlet pressure tapping may be located directly at the pump outlet, provided it is at right angles to the plane of the volute or any other bend formed by the pump casing.

For the pumps of type number greater than 0,5, the straight parallel pipe shall be coaxial with the outlet pipe of the pump and have the same bore. The tapping shall be located in the pipe wall in a plane through the pipe axis at right angles to the plane of the volute or other bend formed by the pump casing.

5.7.2 *Pumps tested with fittings*

If specified in the contract, standard tests shall be carried out on a combination of a pump and

1) associated fittings at the final site installation; or

2) an exact reproduction thereof; or

3) fittings introduced for testing purposes and taken as forming part of the pump itself. (See for examples 5.7.3, 5.7.4, etc.)

Connections on the inlet and outlet sides of the whole combination shall be made in accordance with 5.7.1.

Measurements shall then be taken in accordance with 5.11.2 and 5.11.3.

5.7.3 *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, on either inlet or outlet as described in 5.7.1, cannot be made owing to inaccessibility or submergence, measurements shall be taken in accordance with 6.2.2.3 and 6.2.3.3.

5.7.4 *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 measured. Any thrust bearing would also be more lightly loaded during the test than it would be in the final installation. (See 6.2.4.4.)

5.7.5 *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.

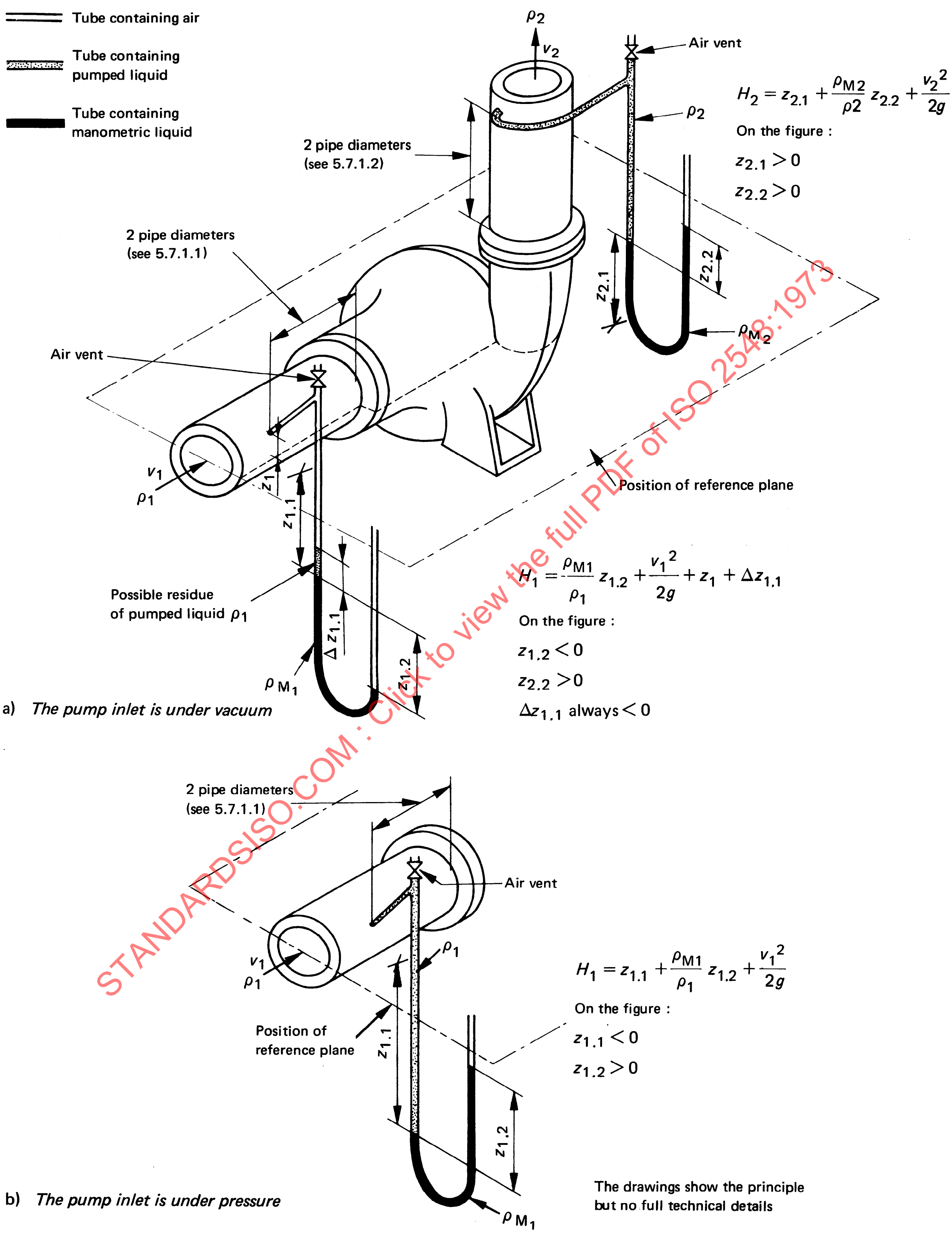
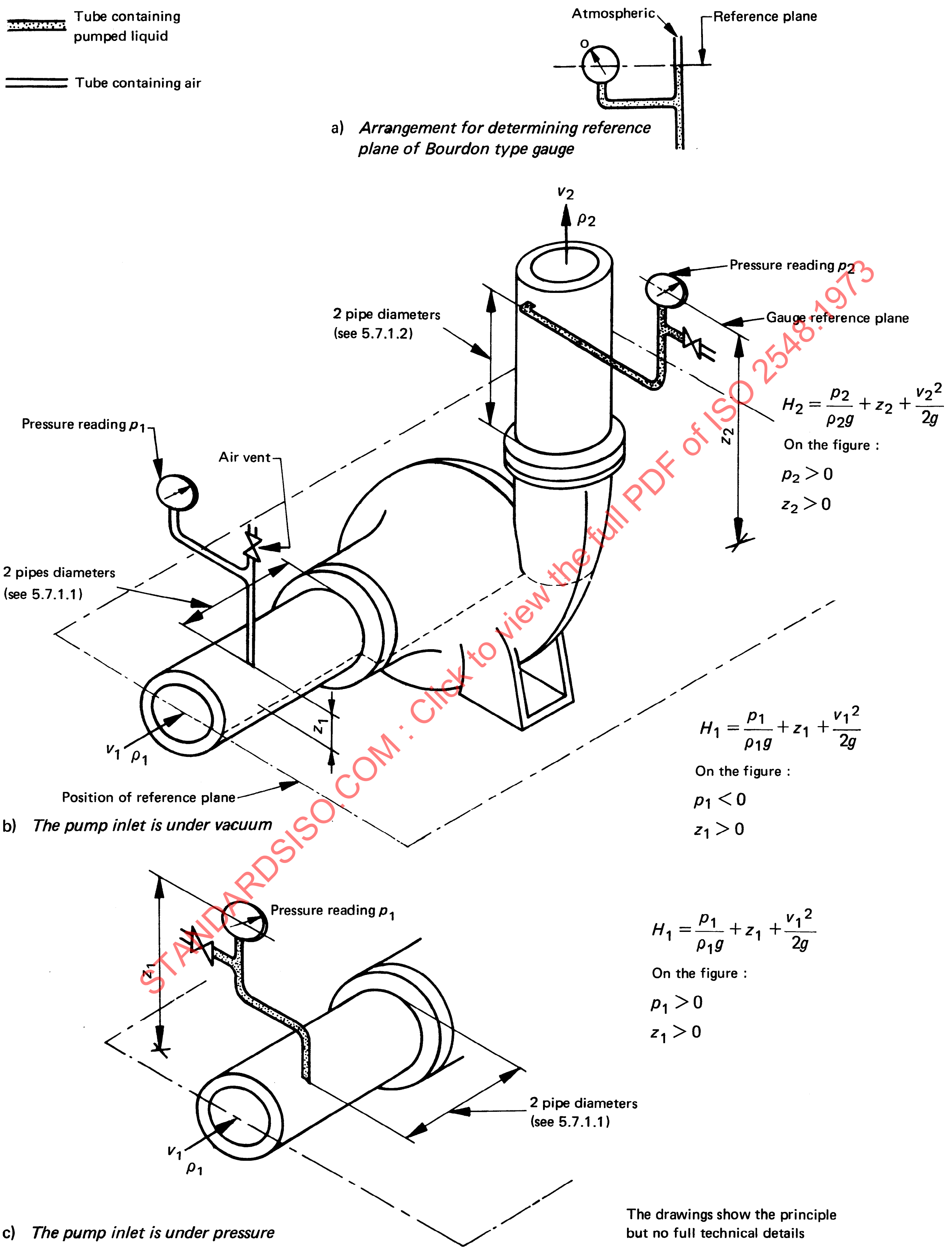


FIGURE 1 — **Test of a centrifugal pump by means of liquid column gauges**



a) *Arrangement for determining reference plane of Bourdon type gauge*

b) *The pump inlet is under vacuum*

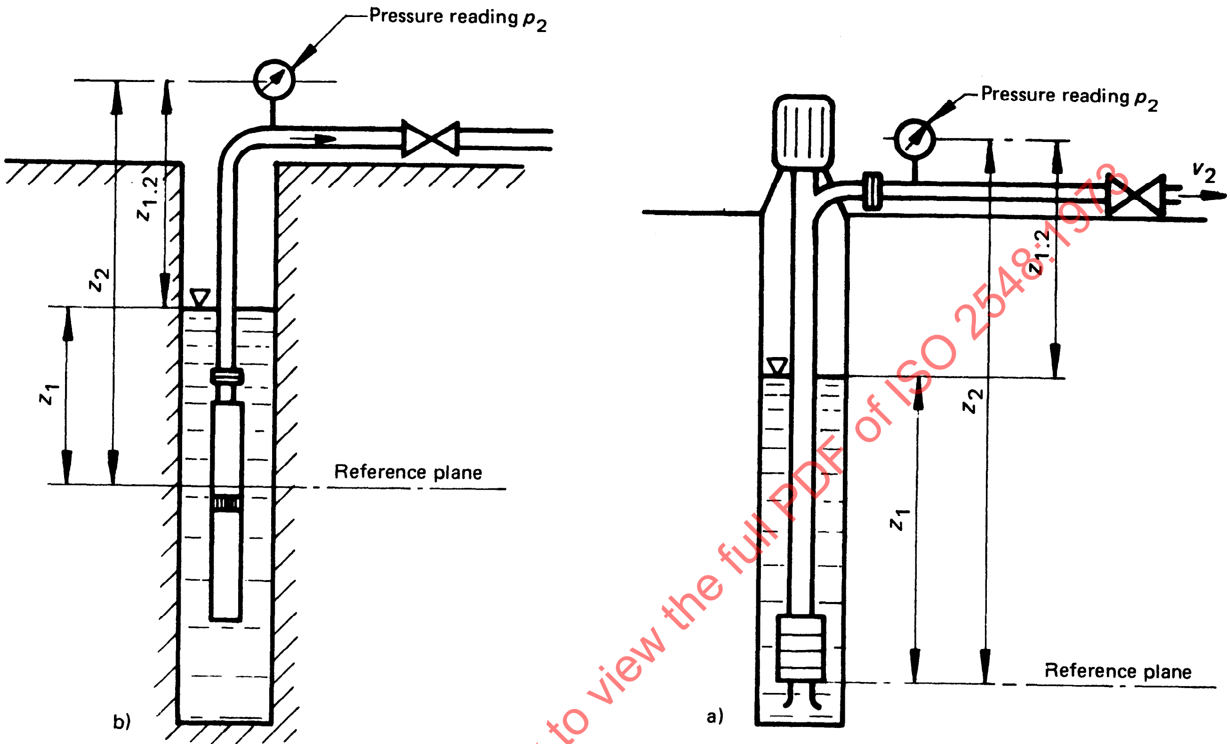
c) *The pump inlet is under pressure*

FIGURE 2 — **Test of a centrifugal pump by means of Bourdon gauges**

$$H_1 = z_1$$

$$H_2 = \frac{p_2}{\rho_2 g} + z_2 + \frac{v_2^2}{2g}$$

$$H = \frac{p_2}{\rho_2 g} + z_{1.2} + \frac{v_2^2}{2g}$$



The drawings show the principle but no full technical details

FIGURE 3 – **Measurement of pump total head *H* for various types of submerged pumps**

$l \geqslant 2\,d$ where d = 2 to 6 mm or 1/10 pipe diameter whichever value is the less

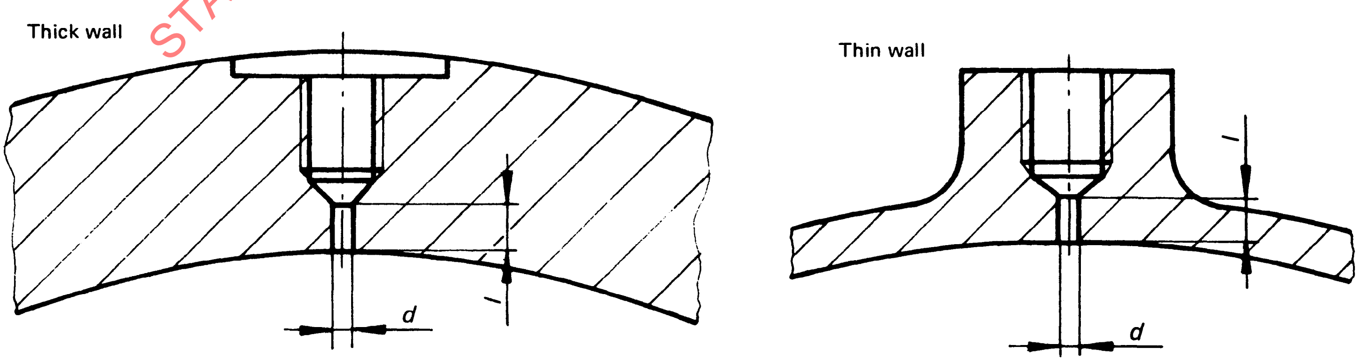


FIGURE 4 – **Requirements for static head tappings**

5.7.6 *Friction losses at inlet and outlet*

The guarantees under 4.1 refer to the pump inlet and outlet flanges, and the pressure measuring points are in general at a distance from these flanges (5.7.1 to 5.7.5). It may be necessary to add to the measured pump total head the head losses due to friction (H_{J1} and H_{J2}) between the measuring points and the pump flanges.

Such a correction should be applied only if

$$H_{J1} + H_{J2} \geqslant 0{,}005\,H$$

If the pipe between the measuring points and the flanges is unobstructed, straight, and of constant circular cross-section,

$$H_J = \lambda \frac{l}{D} \frac{v^2}{2g}$$

The value of λ should be derived from

$$\frac{1}{\sqrt{\lambda}} = -2 \log_{10} \left[\frac{2{,}51}{Re\sqrt{\lambda}} + \frac{k}{3{,}7\,D} \right]$$

where $Re = \frac{vD}{\nu}$ (pure number)

$$\frac{k}{D} = \frac{\text{pipe roughness}}{\text{pipe diameter}} \quad \text{(pure number)}$$

Annex C gives guidance on how to check whether a correction needs to be made, and on how to calculate the correction if necessary.

If the pipe is other than unobstructed, straight, and of constant circular cross-section, the correction to be applied must be the subject of special agreement in the contract.

5.8 Speed of rotation during test (see 4.2.2)

The difference between the specified speed of rotation and the test speed of rotation may be allowed as follows $\left(\frac{n - n_{sp}}{n_{sp}}\right)$:

5.8.1 For flow rate and head :

$$\begin{matrix} +20\ \% \\ -50\ \% \end{matrix}$$

5.8.2 For efficiency :

$$\pm 20\ \%$$

For a combined motor-pump unit, the motor efficiency change between specified and test speeds, shall be established at the time of agreeing the contract.

5.8.3 For (NPSH) tests :

± 20 % provided that the pump flow rate during the test lies within 50 % and 120 % of the flow rate corresponding to maximum efficiency.

NOTE — For tests conforming to the requirements of 7.1.1.1, the above-mentioned variation may always be allowed; for tests conforming to the requirements of 7.1.1.2, it may be allowed for pumps with type numbers less than or equal to 2. For pumps with type numbers greater than 2, agreement shall be reached between the parties concerned.

5.9 Control of head

The test conditions may be obtained, among other methods, by throttling in either or both the inlet and outlet pipes. 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 (see 7.1.2), the flow measuring device (see 6.1.3 — 4th paragraph) or both.

5.10 Execution of tests

The duration of the test shall be sufficient to obtain consistent results, having regard to the degree of accuracy to be achieved.

Where multiple readings are taken to reduce the error margin (see 5.11), they shall be taken at equal intervals of time.

Where, for special reasons, it is necessary to determine performance over a range of operating conditions, a sufficient number of observations shall be taken to establish the performance within the limits of error stated in 5.11.

All measurements shall be made under steady conditions of operation as defined in 5.11. If steady conditions are not achievable, agreement shall be made between the parties concerned on the matter.

If the driving power available during a test on a testing stand is insufficient, and if the test has to be carried out at greatly reduced speed of rotation, the guaranteed characteristics can be adjusted to such reduced speed of rotation in accordance with 5.8.1, 5.8.2, 5.8.3, 9.2.1 or 9.2.2, respectively.

To verify the guarantee point, three measurements shall be recorded, one as close as possible to the guarantee point, and one closely on each side of it.

The test records shall be kept with two copies (one for the purchaser and one for the manufacturer); all test records and recording strips shall be initialled by the chief of tests and the representatives of both parties.

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.

5.11 Test conditions

5.11.1 *Definitions*

For the purpose of this International Standard the following definitions apply :

oscillations : Short oscillation cycles about a mean value occurring during the time that a single observation is being made.

variations : Those changes in value which take place between one reading and the next.

5.11.2 *Permissible oscillations in readings and use of damping*

Where the construction or operation of a pump is such that oscillations of great amplitude are present, measurements may be carried out by means of an instrument capable of providing an integration over at least one complete cycle of oscillation. The calibration of such an instrument shall comply with the provisions of the appropriate clauses.

Restricted damping may be introduced in measuring instruments and their connecting lines where necessary to reduce the amplitude of oscillations to within the values given in Table 4.

TABLE 4 – **Maximum permissible amplitude of oscillations as a percentage of mean value of quantity being measured**

Measured quantity	Maximum permissible amplitude of oscillations %
Rate of fow Head Torque Power	± 6
Speed of rotation	± 2

NOTES

1 Where a 6 % change in flow would result in a calculated 12 % change in head, the maximum permissible amplitude of the observed differential head shall be ± 12 %.

2 In the case of inlet total pressure head and outlet total pressure head measurement, the permissible percentage oscillation shall be calculated on the pump total head.

Where it is possible that damping will significantly affect the accuracy of the readings, the tests shall be repeated using a symmetrical damping device, for example a symmetrical orifice or capillary tube.

5.11.3 *Number of sets of observations*

5.11.3.1 STEADY CONDITIONS

In steady and well controlled test conditions, only one set of readings of individual quantities shall be recorded for the specified test condition. This set shall be recorded only after the observers have been satisfied that the oscillations and variations of the readings have settled down within the limits specified in Tables 4 and 5.

5.11.3.2 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 :

Repeated sets of observations of the measured quantities shall be made at the guarantee point, only speed and temperature being allowed to be controlled. Throttle valve water level, gland, balance water, settings, etc. shall be left completely unaltered. The differences 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 the installation.

A minimum of three sets of observations shall be taken at the guarantee point, and the value of each separate measurement and of the efficiency derived from the measurements in each set 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 will be noted that a wider tolerance is permitted if the number of readings is increased up to the maximum requirement of nine readings.

These tolerances are designed to ensure that the errors due to scatter, taken together with the systematic error limits given in Table 6, will result in overall measurement errors not greater than those given in Table 7.

TABLE 5 – **Limits of variation between repeated measurements of the same quantity (based on 95 % confidence limits)**

Number of sets of observations	Maximum permissible difference between largest and smallest readings of each quantity %	
	Rate of flow Head Torque Power Efficiency	Speed of rotation
3	1,8	1,0
5	3,5	2,0
7	4,5	2,7
9	5,8	3,3

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 observations 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.

5.12 Accuracy of measurement

The limits of measurement errors[1)] laid down in this International Standard are those which refer to measurements taken and to quantities calculated therefrom;

1) See Appendix W.

they apply to the maximum permissible discrepancies between measured and actual performances (see 9.4).

For the purpose of this International Standard, an "error" is defined as a value equal to twice the estimated standard deviation. It is assumed that there is a 95 % probability that the estimated value of the true error will not exceed twice the estimated standard deviation.

This test code specifies the standard methods of measurement and instruments to be used for the determination of rate of flow, inlet total head, outlet total head, pump total head, speed of rotation and pump power input.

Any device or method which by calibration or comparison with ISO documents[1] has been demonstrated to be capable of measuring with systematic errors not exceeding the limits in Table 6 may be used. The devices or methods shall be agreed upon by both parties concerned.

TABLE 6 — **Permissible systematic errors of measuring instruments**

Measured quantity	Permissible limit, %
Rate of flow Pump total head Pump power input	± 2,5
Electrical power input (for overall efficiency tests) Motor efficiency	± 2,0
Speed of rotation	± 1,4

If the recommendations concerning the systematic errors of instruments as given in Table 6, and those concerning the actual test procedure, are followed, it should be assumed that the overall limits of error will not exceed those given below.

TABLE 7 — **Maximum permissible limits of overall errors**

Quantity	Permissible limit, %
Rate of flow Pump total head Pump power input Electrical power input (for overall efficiency tests)	± 3,5
Speed of rotation	± 2,0
Overall efficiency (computed from the rate of flow, total head and electrical power)	± 4,5
Pump efficiency	± 5,0

6 PROCEDURE FOR MEASUREMENT OF RATE OF FLOW, HEAD, SPEED OF ROTATION AND POWER INPUT

The following methods, among others, may be used :

6.1 Measurement of flow rate

6.1.1 *Weighing tank method*

This method is capable only of measuring the mean value of the flow rate during the period concerned.

It is subject to the errors of the weighing, of the time-measuring apparatus employed, of the time taken for the diversion of the flow into and from the weighing tank and those involved in the determination of density.

Details of the accuracy obtainable with this method are given in IEC Publication 193[1].

NOTE — In the case where two tanks are used alternately during the measuring period, the flow being diverted from one to the other, only the times of initial diversion into and final diversion from the measuring system shall be taken into account, not the times of the intermediate diversions from tank to tank.

6.1.2 *Volumetric tank method*

This method, as in the case of the weighing method, is only capable of measuring the mean value of the flow rate during the period concerned.

In every case a leakage test of the tank shall be carried out and correction made for leakage if necessary; where possible, initial calibration shall be carried out by weighing a liquid of known density into the measuring tank. Outdoor tanks shall be adequately sheltered so that the level and the level-measuring devices are not disturbed by wind or rain.

In the case of big outdoor tanks the method is in general subject to errors in measurement of levels which are not stationary and which may be non-uniform. In such a case the levels shall be simultaneously measured within stilling tubes, at not fewer than four widely separated positions within the tank.

Water levels may be measured with hook gauges, float gauges, piezometer or other instruments capable of maintaining the required accuracy.

Details of the accuracies obtainable with this method are given in IEC Publication 193 [1].

6.1.3 *Orifice plates, venturi tubes and nozzles*

The measurement of flow rate may be carried out using devices designed and installed in accordance with ISO/R 541[1] for orifice plates and nozzles and ISO/R 781[1] for venturi tubes. Minimum straight lengths required upstream from the pressure difference device, especially, are given in Table 1 of ISO/R 541 in the case of orifice plates and nozzles, and in Table 1 of ISO/R 781 in the case of venturi tubes.

1) See Appendix W.

For the purpose of this International Standard the pump will be considered to cause a flow disturbance equivalent to a single 90° bend lying in the same plane as the pump volute or the last stage of a multistage pump or the outlet bend of the pump.

The characteristics of these devices are calculated using these ISO documents and calibration is not required.

Care shall be taken to ensure that neither cavitation nor air is present in the flow-measuring devices. Special care shall be taken to ensure that the indications of the device are not affected by air coming out of solution at the control valve. The presence of air can usually be detected by operating the air vents on the measuring device.

Manometers used for differential pressure measurement shall be of the liquid column type and shall meet the requirements of 6.2.6.

ISO 2186[1)] gives indications as to the connecting pipes.

6.1.4 *Notches, weirs and flumes*

Recommendations for the construction and installation of notches, weirs and flumes are given in ISO 1438[1)], to which reference should be made.

For the purposes of this International Standard the smallest scale division of any instrument used for observing head shall be not greater than that corresponding to 1,5 % of the flow.

6.2 Measurement of head

6.2.1 *Pressure tappings and instrument connecting lines*

Static pressure tappings shall comply with the requirements shown in Figure 4 and be free from burrs and irregularities and flush with, and normal to, the inner wall of the pipe.

The diameter of the pressure tappings shall be between 2 and 6 mm or equal to 1/10 of the pipe diameter, whichever is less. The length of a pressure tapping hole shall be not less than twice its diameter.

The bore of the pipe containing the tappings shall be clean, smooth and resistant to chemical reaction with the liquid being pumped. Any coating such as paint applied to the bore shall be intact. If the pipe is welded longitudinally, the tapping hole shall be displaced as far as possible from the weld.

Pipes connecting pressure tappings to possible damping devices (see 5.11.2) and to instruments shall be at least equal in bore to the bore of the pressure tappings. The system shall be free from leaks.

It is recommended that transparent tubing be used so as to allow determination of the amount of water or air in the tubing.

ISO 2186[1)] gives indications as to the connecting pipes.

1) See Appendix W.

6.2.2 *Inlet total head*

6.2.2.1 Installation in accordance with 5.7.1.1

These installations and the corresponding formulae are given in Figures 1 and 2.

6.2.2.2 Installation in accordance with 5.7.2

Where a pump is tested in combination with fittings forming part of the site or test installation, the provisions of 6.2.2.1 shall be applied to the inlet flange of the fittings and not to the inlet flange of the pump.

This procedure debits against the pump all head losses caused by fittings on the inlet side.

6.2.2.3 Installations in accordance with 5.7.3 and 5.7.4

The inlet total head is equal to the positional head with respect to the reference plane of the still surface of the liquid in which the pump is tested or from which it draws, plus the pressure head equivalent to the gauge pressure on that surface.

This assumption debits against the pump all head losses caused by fittings on the inlet side.

6.2.3 *Outlet total head*

6.2.3.1 Installations in accordance with 5.7.1.2

These installations and the corresponding formulae are given in Figures 1 and 2.

6.2.3.2 Installations in accordance with 5.7.2

Where a pump is tested in combination with fittings forming part of the site or test installation, the provisions of 6.2.3.1 shall be applied to the outlet flange of the fittings and not to the outlet flange of the pump.

This procedure debits against the pump all head losses caused by fittings on the outlet side.

6.2.3.3 Installations in accordance with 5.7.3 and 5.7.4

These installations and the corresponding formulae are given in Figure 3.

However, if the pump discharges into a sump with a free surface, the outlet total head is equal to the positional head of the still surface of the liquid into which the pump delivers, plus the gauge pressure head.

This assumption debits against the pump all head losses caused by fittings on the outlet side.

6.2.4 *Total inlet and outlet heads – Special cases*

It will prove necessary to permit exceptions from the above-mentioned standard arrangements in the following cases :

6.2.4.1 Pumps conforming to the final site installation

During the acceptance test, the pump shall be fitted with the pipe arrangements corresponding to the final arrangement at site. In this case the friction losses between the test point for measuring the inlet pressure and the inlet flange, as well as between the outlet flange and the test point for measuring the outlet pressure, shall be determined in accordance with the method mentioned in 5.7.6 and added to the sum of the differences of positional head, of pressure head and of velocity head.

6.2.4.2 Pumps with inaccessible ends

If the inlet or outlet or both sides of the pump are inaccessible, the procedure prescribed above shall be followed in measuring the pump's head. Under certain circumstances, friction losses, such as mentioned in 5.7.6 and 6.2.4.1, shall be taken into account.

6.2.4.3 Submersible pumps

If the outlet flange of this type of pump is, for practical purposes, defined as placed at a certain distance from the pump proper, and is thus preceded by an outlet pipe length and a bend or bends being always parts of the installation, the measurement of outlet head shall be made in accordance with 5.7.2.

6.2.4.4 Deep-well pumps

In this case, friction losses between the pressure measuring points and the inlet or outlet flanges, respectively, that may have to be taken into account, shall be determined in accordance with the method given in 5.7.6 and Annex C. Friction losses on suction are primarily caused by resistance to flow within the inlet strainer, the foot valve, and the inlet pipe. All of these head losses shall as far as possible be indicated at the time the contract is made by the pump manufacturer if he supplies such accessories, or by the purchaser if they are fitted by the latter. Should it prove impossible to submit such data, the purchaser and the manufacturer, prior to the acceptance test, shall arrive at an agreement concerning the flow resistance data to be applied.

Friction losses at outlet result from resistance to flow within the column-pipe and the outlet bend.

Since deep-well pumps in general are not tested with the entire stand pipe attached, unless the acceptance test is performed at site, the pipe friction losses in regard to the pump total head shall be estimated and stated by the manufacturer to his purchaser.

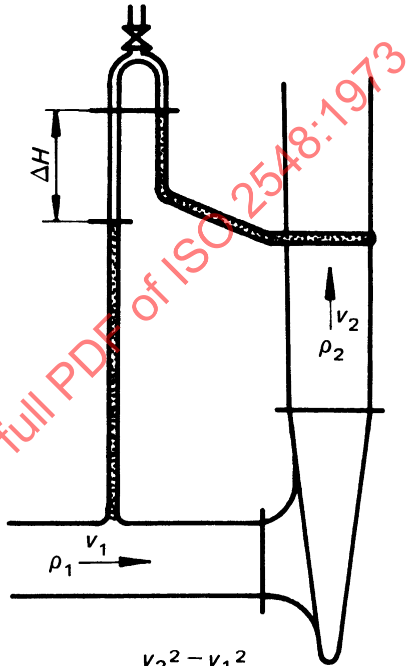
Should it be considered necessary to verify the data indicated by an acceptance test at site, such a test shall be specified in the supply contract.

For tests on installations conforming to the requirements of 5.7.2, 5.7.3 and 5.7.4, the guarantees also apply to fittings.

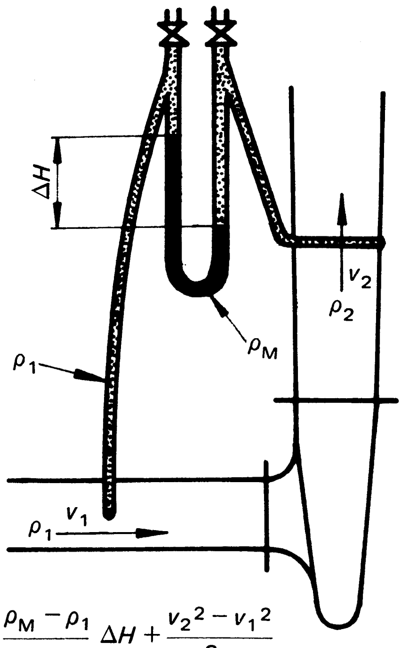
6.2.5 *Pump total head*

The pump total head is calculated in accordance with the definition given in 3.2.3.8. However, in certain cases the pump total head may be measured using one differential pressure device.

This type of installation and the corresponding formulae are given in Figure 5.



$$H = \Delta H + \frac{v_2^2 - v_1^2}{2g}$$



$$H = \frac{\rho_M - \rho_1}{\rho_1} \Delta H + \frac{v_2^2 - v_1^2}{2g}$$

This equation is valid for $\rho_1 = \rho_2$ which may be assumed for class C tests.

FIGURE 5 – **Direct measurement of pump total head**

When this is deemed preferable, the pump total head may be replaced by an expression giving the increase in specific energy of the fluid conveyed by the pump ($Y = gH$, see 3.2.3.9).

The "specific energy" increase is obtained by multiplying both sides of the pump total head equation given above by g.

6.2.6 *Instruments for pressure measurement*

6.2.6.1 LIQUID COLUMN MANOMETERS

No calibration is required.

The minimum distance between two scale graduations shall be 1 mm.

If possible, the use of differential liquid columns less than 50 mm high shall be avoided. If this is impossible, attention shall be specially drawn to errors of measurement.

The length of the liquid column may be modified by using one manometric liquid in place of another.

For readings below 100 mm of liquid, the bore of manometer tubes shall be 6 mm at least for mercury and 10 mm for water and other liquids.

The cleanliness of the liquid in the manometer shall be maintained to avoid errors due to variation of surface tension.

The design of the manometers shall be such that parallax errors are minimized.

Water column manometers may be either open ended (for low pressure measurement only) or closed with the air in the column connecting both limbs compressed to the amount required to permit the differential head to be read on the scale.

The use of the liquid column manometer is shown diagrammatically in Figures 1 and 5, to which reference should be made.

Connections between the pipes where pressure is measured and the manometer shall be made as shown diagrammatically in Figure 1.

It is essential that there is no break in continuity (for example, by air pockets through failure to vent properly) of the water between the pipe and the reading surface in the manometer.

6.2.6.2 BOURDON DIAL GAUGES

When this type of gauge is used for inlet and outlet pressure measurements, to ascertain pump total head, it is recommended that the difference between two consecutive scale graduations be within 1,5 and 3 mm for both measurements, and that this difference corresponds to not more than 5 % of the pump total head.

6.3 Measurement of the speed of rotation

The speed of rotation shall be measured by counting revolutions for a measured interval of time, by a direct-indicating tachometer or, in the case of a pump driven by an a.c. motor, from observations of the mean frequency and motor slip data either directly measured (for example, using a stroboscope) or supplied by the motor manufacturer.

Where the speed of rotation cannot be directly measured (for example, for immersed pumps), it is usually sufficient to establish the frequency and voltage.

6.4 Measurement of pump power input

The pump power input shall be derived from measurement of the speed of rotation and torque, or determined from measurements of the electrical power input to an electric motor of known efficiency, directly coupled to the pump.

6.4.1 *Measurement of torque*

Torque shall be measured by a suitable dynamometer, capable of complying with the requirements of 5.11.

6.4.2 *Electric power measurements*

Where the electrical power input to an electric motor coupled directly to the pump is used as a means of determining the pump power input, the following conditions shall be observed :

a) the motor shall be operated only at conditions where the efficiency is known with sufficient accuracy;

b) motor efficiency shall be determined in accordance with the recommendations of IEC Publication 34-2[1].

The electric power input to the driving motor shall be measured by the two-wattmeter method in the case of a.c. motors. This allows the use of two single-element wattmeters, or one double-element wattmeter or one single-element wattmeter and suitable switches.

In the case of a d.c. motor, either a wattmeter or an amperemeter and a voltmeter may be used.

The type and grade of accuracy of the indicating instruments for measuring electrical power shall be in accordance with IEC Publication 51[1].

Where the power input to an electric motor coupled to an intermediate gear, or the speed of rotation and torque measured by a dynamometer between gear and motor, are used as a means for determining the guaranteed pump power input, it shall be stated in the contract in what way the losses of the gear shall be determined.

6.4.3 *Pumps with inaccessible ends*

In the case of combined motor-pump units (for example submersible pump or monobloc pump; or separate pump and motor with overall efficiency guaranteed), the power of

1) See Appendix W.

the machine unit shall be measured at the motor terminals if accessible. When a submersible pump is involved, the measurement shall be effected at the incoming end of the cables; cable losses shall be taken into account and specified in the contract. The efficiency given shall be that of the combined unit proper, excluding the cable and the starter losses.

6.4.4 *Deep-well pumps*

In this case the power absorbed by the thrust bearing and the vertical shafting and bearings shall be taken into account.

Since deep-well pumps in general are not tested with the entire stand pipe attached, unless the acceptance test is performed at site, the thrust and vertical shaft bearing losses in regard to power and efficiency shall be estimated and stated by the manufacturer to his purchaser.

6.5 Measurement of pumping unit efficiency

To determine the efficiency of a pumping unit, only the power input and output are measured, with the driver working under conditions specified in the contract. In this test, the proportion of losses between driving agent and pump is not established, nor any losses associated with intermediate machinery such as gear box or variable speed device.

7 CAVITATION TESTING

7.1 General

When the contract specifies a (NPSH), a test may be conducted to verify that the (NPSH) required by the pump is equal to or less than the specified (NPSH).

In no case shall the cavitation tests be used to check that the pump will be free from cavitation erosion during its service life.

7.1.1 *Test types*

There are two distinct possible types of cavitation test :

- a check may be made simply to show that the pump is sufficiently free of cavitation at the specified duty and (NPSH). This type of test is described in 7.1.1.1;

- in the other type, cavitation performance is explored more fully by reducing (NPSH) until measurable effects are noted. This type of test is described in 7.1.1.2.

7.1.1.1 A test at the specified flow rate and (NPSH). The pump characteristic can be assumed to be free of the effects of cavitation if another test at a higher (NPSH) gives the same total head at the same rate of flow.

7.1.1.2 A safety margin to be agreed in the contract shall be added to the (NPSH) which causes a drop of $(3 + x)$ % in total head or efficiency at a given rate of flow, or in rate of flow or efficiency at a given total head. From this test the behaviour of the pump at various departures from the specified (NPSH) may be judged.

The value of x will be :

$$x = \frac{K}{2}$$

The resulting (NPSH) shall be equal to or less than the required (NPSH).

When negotiating the safety margin, account shall be taken of the type of pumps, of the number of stages, of the physical properties of the liquid to be pumped and of materials of construction and the operating conditions to be expected.

7.1.2 *Methods of varying the (NPSH)*

The following methods may be used :

7.1.2.1 The pump is installed in a closed pipe loop (Figure 6) in which the pressure level or, by an alteration of temperatures, the vapour pressure may be varied without changing the pump head or rate of flow until cavitation occurs in the pump.

Cavitation in outlet and inlet regulating valves may make this test more difficult and special valves may be required.

Arrangements for cooling or heating the liquid in the loop may be needed in order to maintain the required temperature, and a gas separation tank may also be required. The tank shall be of sufficient size and so designed as to prevent the entrainment of gas in the pump inlet flow.

De-aeration of water used for a cavitation test is necessary if the pump is to be used in practice with de-aerated water.

Stilling screens may be needed if $\frac{Q}{A} > 0,25$ m/s, where A is the cross-sectional area of the tank.

7.1.2.2 The pump draws liquid through an unobstructed suction pipe from a sump in which the level of the free liquid surface may be adjusted (Figure 7).

7.1.2.3 The pressure of the liquid entering the pump is adjusted by means of a throttle valve installed in the inlet pipe at the lowest practical level (Figure 8).

Cavitation in the flow through a throttle valve can sometimes be prevented by using two or more throttle devices connected in series or by arranging for the throttle valve to discharge directly into a closed vessel or a large diameter pipe interposed between the throttle and the pump inlet. Baffles and a means for extracting air from such a vessel may be needed, especially when the (NPSH) is low.

When the throttle valve is to be partially closed and it is situated at a distance less than 12 inlet diameters from the pump inlet flange, it is necessary to make sure that the pipe is full of liquid at the position of the inlet pressure tappings.

7.2 Determination of (NPSH) required by the pump

Tests described in 7.1.1.2 can be conducted by any of the methods indicated in Figures 6 to 8. It is possible to vary two control parameters and thus keep flow rate constant during a test, but this is usually more difficult.

7.3 Limits of error in determination of specified (NPSH)

The maximum limits of error concerning specified (NPSH) measurements shall be

5,3 % of the measured (NPSH), or

0,2 m,

whichever is the greater, provided that the measurements are made with a liquid column manometer.

The case of tests with liquids at high temperature or near their critical points should be studied with special care in the contract.

7.4 Measurement of pump head, outlet flow rate, speed of rotation, power input (if necessary) and vapour pressure

The requirements of section 6 regarding the measurement of head, outlet rate of flow, speed of rotation and power input shall also apply during cavitation tests. If the test conditions are so unsteady as to require repeated readings, variations of specified (NPSH) are permitted up to a maximum of

1,5 times the values given for head in Table 5; or

0,2 m,

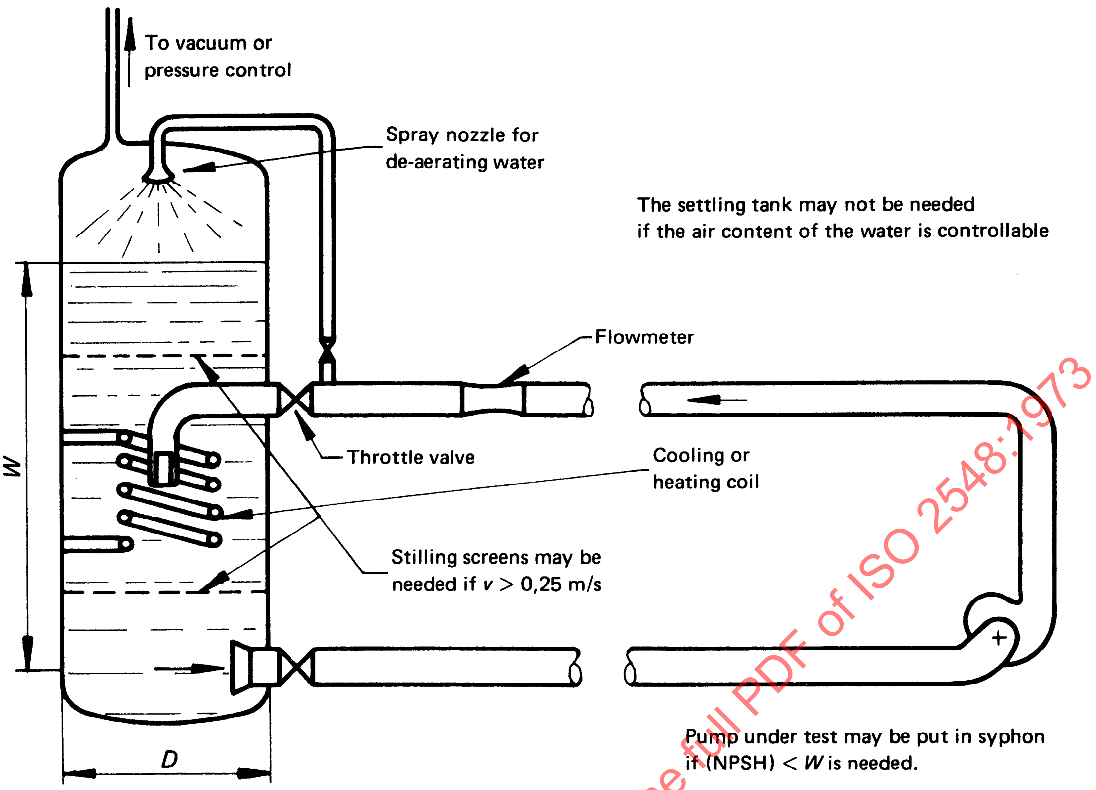
whichever is the greater.

Particular care is needed to ensure that in the flow measurement cavitation does not affect the accuracy of the flowmeter. It is also necessary to take care to avoid the ingress of air through joints and glands.

The vapour pressure of the test liquid entering the pump shall be determined with sufficient accuracy to comply with 7.3. When the vapour pressure is derived from standard data and the measurement of the temperature of the liquid entering the pump, the necessary accuracy of temperature measurement may have to be demonstrated.

The active element of a temperature-measuring probe shall be not less than 1/8 of the inlet pipe diameter from the wall of the inlet pipe. If the immersion of the temperature-measuring element in the inlet flow is less than that required by the instrument manufacturer, then a calibration at that immersion depth may be required.

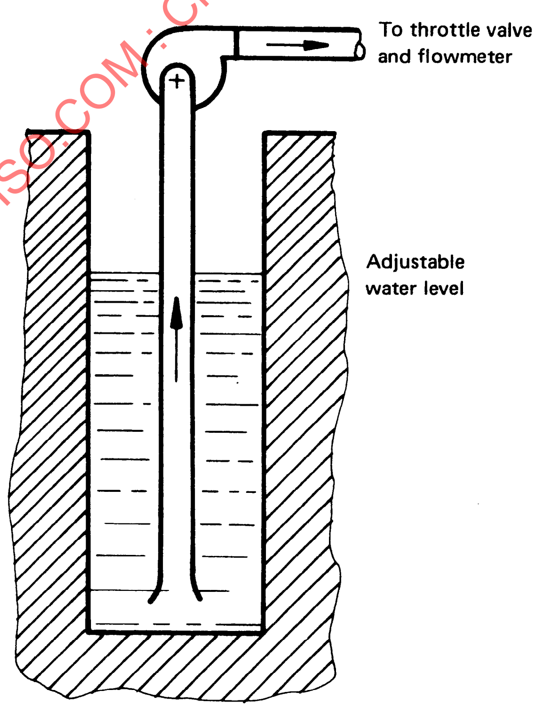
Care shall be taken to ensure that temperature-measuring probes inserted into the pump inlet pipe do not influence the measurements of inlet pressure.



NOTE — Cooling by means of a coil may be replaced by an injection of cool water above the liquid-free surface and an extraction of heated water.

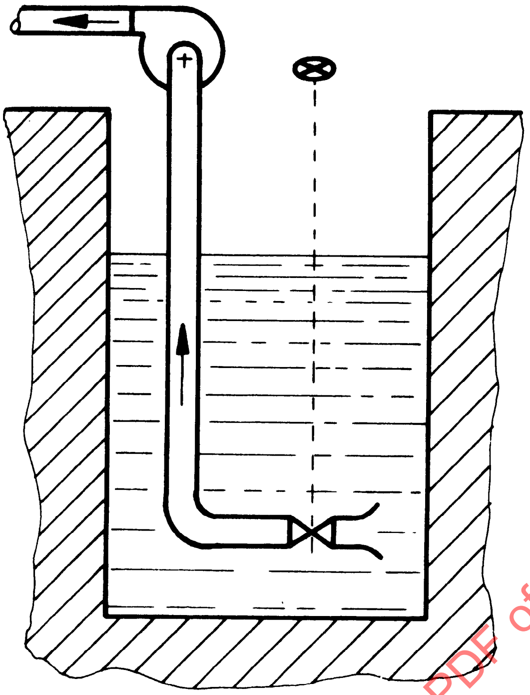
The drawings show the principle but no full technical details.

FIGURE 6 — **Cavitation tests — Variation of (NPSH) by means of a closed loop (see Figures 1, 2 and 3)**



The drawings show the principle but no full technical details

FIGURE 7 — **Cavitation tests — Variation of (NPSH) by control of liquid level at inlet (see Figures 1 and 2)**



The drawings show the principle but no full technical details

FIGURE 8 – **Cavitation tests – Variation of (NPSH) by means of a throttle valve at inlet (see Figures 1 and 2)**

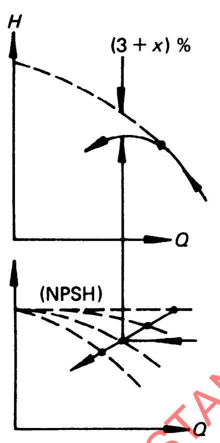
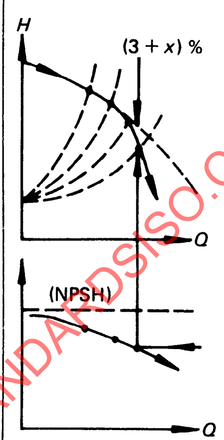
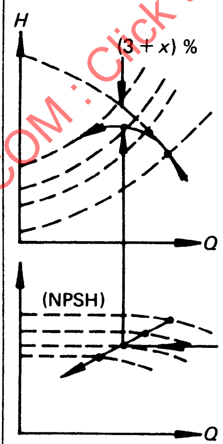
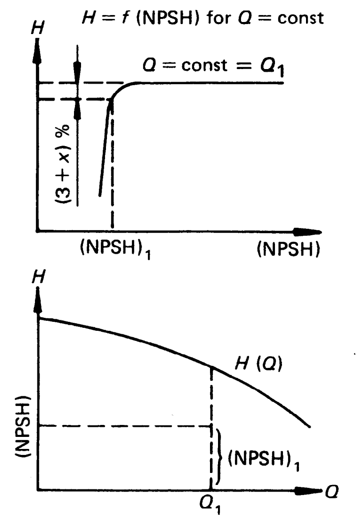
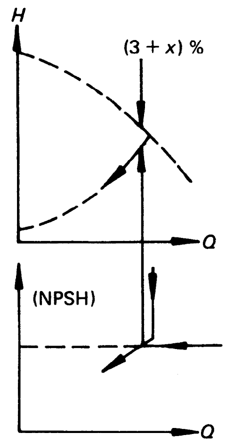
Type of installation	Open sump	Open sump	Open sump	Open sump	Closed loop	Closed loop	Closed sump or loop
Independent variable	inlet throttle valve	outlet throttle valve	water level	inlet throttle valve	pressure in the tank	reference pressure	temperature (vapour pressure)
Constant	outlet throttle valve	inlet throttle valve	inlet and outlet throttle valves	flow rate	flow rate	inlet and outlet throttle valves	
Quantities the variation of which is dependent on control	head, flow rate, (NPSH), water level	head, flow rate, (NPSH), water level	head, flow rate, (NPSH)	outlet throttle valve (for constant flow rate), head (NPSH)	head, (NPSH) outlet throttle valve (for constant flow rate, when head begins to drop)	head, flow rate (NPSH) } after onset of cavitation	
Head characteristic curve **(NPSH) characteristic curve**							

FIGURE 9 — **Methods of determining required (NPSH) for $\Delta H/H = (3 + x)$ %**

8 TESTS ON PUMPS FOR LIQUIDS OTHER THAN CLEAN COLD WATER

The performance of a pump may vary 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 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.

8.1 Characteristics of "clean cold water"

The characteristics of the water corresponding to what is called in this International Standard "clean cold water" shall be within the limits indicated in Table 8.

TABLE 8 — **Specification of "clean cold water"**

Characteristic	Unit	max.
Temperature	°C	40
Viscosity	m^2/s	$1{,}75 \times 10^{-6}$
Mass density	kg/m^3	1 100
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.

8.2 Characteristics of liquids for which clean, cold water tests are acceptable

Pumps for liquids other than clean cold water may be tested for head, flow rate and efficiency with clean cold water if the liquid is within the specification in Table 9.

TABLE 9 — **Characteristics of liquids accepted as "clean cold water"**

Characteristics of liquids	Unit	min.	max.
Viscosity	m^2/s	no limit	10×10^{-6}
Mass density	kg/m^3	450	2 000
Non-absorbent free solids content	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.

9 ANALYSIS OF TESTS

9.1 Test data required for the analysis

The quantities required to verify the characteristics guaranteed by the manufacturer are given in 4.1.

Methods for measuring these quantities are given in section 6.

9.2 Translation of the test result to the guarantee basis

Such translation serves to determine whether the guarantee would have been fulfilled if the tests had been conducted under the same conditions as those on which the guarantee is based.

9.2.1 *Translation of the test results into data based on the specified speed of rotation or frequency*

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 deviations in speed of rotation from the specified speed of rotation n_{sp} do not exceed the permissible variations stated in 5.8, the measured data on the discharged flow rate Q, the total head H, the power input P, the net positive suction head (NPSH) and the efficiency η, can be translated as follows :

$$Q_{sp} = Q\left(\frac{n_{sp}}{n}\right)$$

$$H_{sp} = H\left(\frac{n_{sp}}{n}\right)^2$$

$$P_{sp} = P\left(\frac{n_{sp}}{n}\right)^3$$

$$(\text{NPSH})_{sp} = (\text{NPSH})\left(\frac{n_{sp}}{n}\right)^2$$

$$\eta_{sp} = \eta$$

If the deviations in speed of rotation from the specified speed of rotation n_{sp} exceed the permissible variations stated in 5.8, it will be necessary to stipulate the formula for translating the test results to the basis of the specified speed of rotation.

In the case of combined motor-pump units or where the guarantees are with respect to an agreed frequency and voltage instead of an agreed speed (see 4.1.3.4) the flow rate, pump total head, power input, and efficiency data are subject to the above-mentioned translation laws, provided that n_{sp} is replaced by the frequency f_{sp} and n by the frequency f. Such translation, however, shall be restricted to the cases where the frequency during the acceptance test varies by no more than 1 % from the frequency prescribed for the characteristics under guarantee. If the voltage used in the acceptance test is no more than 5 % above or below the voltage on which the guaranteed characteristics are based, the other operational data require no change.

If the above-mentioned tolerances, i.e. 1 % for frequency and 5 % for voltage, are exceeded, it will be necessary for the purchaser and the manufacturer to arrive at an agreement.

9.2.2 *Tests made with (NPSH) different from that guaranteed*

Pump performance at a high (NPSH) cannot be accepted (after correction for speed of rotation within the permitted limits of 5.8.3) to indicate the performance at a lower (NPSH).

Pump performance at a low (NPSH) can be accepted after correction for speed of rotation within the permitted limits of 5.8.3, to indicate the performance at a higher (NPSH) provided that the absence of cavitation has been checked in accordance with 7.1.1.1.

9.3 Measuring inaccuracies

All measurements are inevitably subject to inaccuracies, even if the measuring procedure and the instruments used, as well as the analysis directives, fully comply with prevailing acceptance rules. When comparing the test results with the guaranteed characteristics, these inaccuracies shall be given adequate consideration. The fact should be stressed that the term "measuring inaccuracies" merely covers the errors that are unavoidable with all measurements; they refer in no way to the pump and the guaranteed characteristics. The maximum permissible limits of overall error for the quantities concerned for class C measurements are defined in Table 7.

9.4 Verification of the guarantee

9.4.1 *Curves QH and Qη*

Guarantee points $Q_G H_G$ and $Q_G \eta_G$ are plotted on a graph and a continuous curve is then drawn through the measured points QH and another through the points Q/η of which Q is measured and η is calculated.

If the test is made at a value of speed that is different from that specified as relevant to the particular guaranteed values, the test points shall be corrected to the specified speed of rotation in accordance with 9.2. Similarly, if the test is made at a value of frequency different from that relevant to the particular guaranteed values, the tests shall be corrected to the specified frequency.

Tolerances $\pm X_Q$ and $\pm X_H$ respectively shall be applied to the guaranteed duty point QH. These tolerances include the maximum permissible limits of overall error e_Q and e_H (see Table 7) and the constructional tolerance.

In the absence of a specific agreement as to the values to be used, the following values may be taken :

$$X_Q = 0{,}07$$

$$X_H = 0{,}04$$

If the guarantee point lies at a vertical distance $\pm \Delta H$ and a horizontal distance $\pm \Delta Q$ from the test curve (see Figure 10), the following shall be evaluated :

$$\left(\frac{H_G \cdot X_H}{\Delta H}\right)^2 + \left(\frac{Q_G \cdot X_Q}{\Delta Q}\right)^2 \geqslant 1$$

Thus, if the total amount is greater than or equal to 1, the guarantee condition will be deemed to have been met, and if the total amount is less than 1, the guarantee condition has not been achieved.

9.4.2 *Efficiency*

The efficiency shall be derived from the measured QH curve where it is intersected by the straight line passing through the specified duty point $Q_G H_G$ and the zero of the QH axes.

The efficiency at the point of intersection shall be at least 95 % of that specified.

For combined motor-pump units this value is 95,5 %.

These values result only from the measuring errors (see Table 7).

9.4.3 *Pump power input*

The pump power input within the range defined in 9.4.1 by the tolerances $\pm X_Q$ and $\pm X_H$, shall not exceed that agreed between the manufacturer and purchaser at the time of contract. This value applies to the conditions of use of the pump as specified in the contract.

Such an agreement may have to take into account different transmission losses and different gland and seal torques between works test and site operation.

9.5 Test report

After scrutiny of the test results, the latter shall be summarized in a report, with as many copies as there are parties. The test report shall be signed either by the chief of tests alone or by him together with the representatives of the manufacturer and the purchaser.

The test report shall contain the following information :

a) place and date of the acceptance test;

b) manufacturer's name, type of pump, serial number, and possibly year of construction;

c) guaranteed characteristics, operational conditions during the acceptance test;

d) specification of the pump's drive;

e) description of the test procedure and the measuring apparatus used including calibration data;

f) observed readings;

g) evaluation and analysis of test results;

h) conclusions :

1) comparison of the test results with the guarantees;

2) determination whether the guarantees covering certain specific areas were completely or only partly fulfilled or not fulfilled at all;

3) recommendation whether the pump can be accepted or should be rejected and under what conditions;

4) if the guarantees are not fully satisfied the final decision whether the pump can be accepted or not is up to the purchaser.

5) statements arising out of action taken in connection with any special agreements that were made.

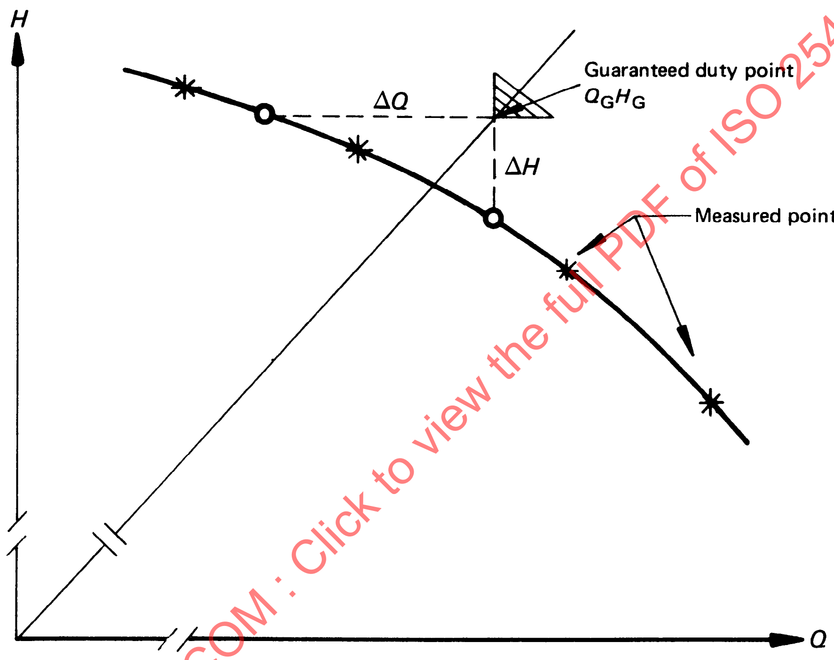


FIGURE 10 — **Curve *QH* for the verification of the guarantee**

ANNEX A

EFFECT OF PRE-SWIRL INDUCED BY THE PUMP

Errors in the measurement of pump inlet head can occur at part capacity due to pre-swirl. This can be detected and corrected on the following basis :

The differential head is measured between the specified inlet measuring section and another position further upstream where the pre-swirl induced by the pump is known to be absent (for example the sump). This differential head should follow a quadratic law with flow; any departure from this law will show the amount by which an inlet head measurement must be corrected for the effect of pre-swirl induced by the pump.

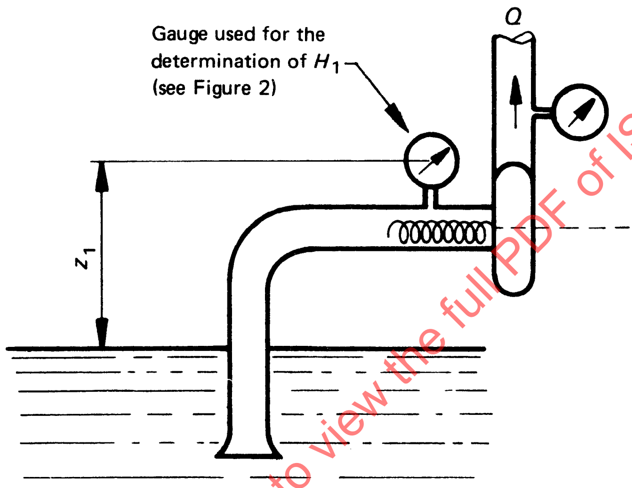


FIGURE 11 – **Example of installation with pre-swirl**

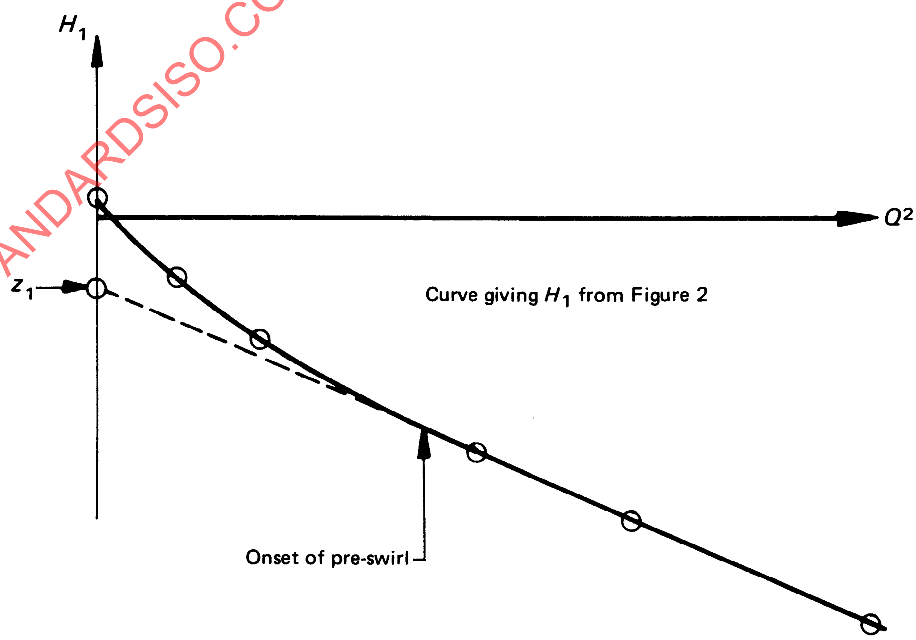


FIGURE 12 – **Correction of measured inlet head**