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Liquid pumps and installation — General terms — Definitions, quantities, letter symbols and units

Pompes pour liquides et installations — Termes généraux — Définitions, grandeurs, symboles littéraux et unités

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 17769 was prepared by Technical Committee ISO/TC 115, *Pumps*.

Liquid pumps and installation — General terms — Definitions, quantities, letter symbols and units

1 Scope

This International Standard deals with terms, letter symbols and units related to the flow of liquids through rotodynamic and positive displacement liquid pumps and associated installations. It serves as a means of clarifying communications between the installation designer, manufacturer, operator and plant constructor.

This International Standard identifies the units in common usage but, all other legal units can be used.

This International Standard deals solely with conditions described by positive values for the rate of flow and pump head. The definitions are set out showing first the most common form of a quantity followed by some frequently used variants. Other variants can be constructed and appropriate symbols evolved using the symbols and subscripts shown. Prefixes such as “working” and “design” can also be applied to the defined quantities.

This International Standard is not concerned with terms, letter symbols and units referring to the component parts of rotodynamic and positive-displacement pumps and installations.

Whenever possible, symbols and definitions conform to those used in ISO 31-0 and ISO 1000, with further explanations where these are deemed appropriate. Some deviations have been incorporated for reasons of consistency.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 31-0, *Quantities and units — Part 0: General principles*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General definitions

3.1.1 General terms

3.1.1.1
pump
mechanical device for moving fluids including the inlet and outlet connections as well as, in general, the shaft ends

3.1.1.2
pump unit
assemblage of mechanical devices including the **pump** (3.1.1.1), the **driver** (3.1.17.23) together with transmission elements, baseplate and any auxiliary equipment

3.1.1.3
installation
arrangement of pipes, supports, foundations, controls, drives, etc. into which the pump or pump unit is connected in order to achieve the service for which it was acquired

3.1.1.4
system
those parts of an **installation** (3.1.1.3) that, together with the pump, determine the functional performance of the installation

3.1.1.5
conditions
all parameters (for example temperatures, pressures) determined by the application and the pumped liquid which affect the function and performance of the system

3.1.2 Prefixes usable with some terms in this International Standard

3.1.2.1
design
values used in the design of a pump for the purpose of determining the performance, the minimum permissible wall thickness and the physical characteristics of the different parts of the pump

NOTE It is recommended to avoid the use of the word “design” in any term (such as design pressure, design power, design temperature or design speed) in the purchaser's specifications. This terminology should be used only by the equipment designer and manufacturer.

3.1.2.2
rated
specified performance condition selected to ensure that the operating performance is achieved by the pump or pump unit when installed

3.1.2.2.1
rated conditions
conditions [**driver** (3.1.17.23) excluded] that define the guarantee values necessary to meet all defined operating conditions, taking into account any necessary margins

3.1.2.3
operating
one or several settings for which the pump is intended to be used

NOTE The operating settings should be within the allowable working range.

3.1.2.3.1
operating conditions
all parameters determined by a given application and pumped liquid

NOTE These parameters influence the type and materials of construction.

EXAMPLE Operating temperature, operating pressure.

3.1.2.4
pressure/temperature rating
pressure/temperature limit of a component at a given design and material

See Figure A.2.

3.1.2.5
normal
conditions at which usual operation is expected

3.1.2.6
allowable
limiting values and/or ranges of conditions for a pump as built, owing to the material and the design

3.1.2.7 Working

3.1.2.7.1
working
conditions existing at the moment when an event is noted or a quantity is measured

3.1.2.7.2
allowable working
limiting values and/or ranges of conditions at which the pump unit can be operated, owing to the material and the design

3.1.2.8
test
terms that describe the characteristics of the pump or fluid or the conditions that exist during an examination

3.1.2.9
nominal
appropriate rounded value of a magnitude to designate a component, a unit or a device

3.1.3 Rate of flow

NOTE These definitions refer to the quantities of liquid pumped.

3.1.3.1
mass rate of flow
q
mass of liquid discharged from the outlet area of the pump in a given time

NOTE 1 The mass rate of flow is expressed in units of kilograms per second, kilograms per hour, tonnes per hour (the tonne is considered a deprecated unit).

NOTE 2 It is preferable not to include in the mass rate of flow losses inherent to the pump, i.e. discharge necessary for the following, if they are taken from a point before the flow-measuring section:

a) hydraulic balancing of axial thrust;

b) cooling of bearings of the pump;

c) liquid seal to the packing;

d) leakage from fittings, internal leakage, etc.

NOTE 3 It is preferable to include in the mass rate of flow quantities used for other purposes, such as the following, if they are taken from a point before the flow-measuring section:

a) cooling of motor bearings;

b) cooling of gearbox (bearings, oil cooler), etc.

Whether and how these flows should be taken into account depends upon the location of their source and relationship to the flow-measuring section.

3.1.3.2
rate of flow
volume rate of flow
Q
volume of liquid discharged from the outlet area of the pump in a given time as given by Equation (1):

$$Q = \frac{q}{\rho} \tag{1}$$

where

q is the **mass rate of flow** (3.1.3.1);

ρ is the **density** (3.1.16.1), expressed in appropriate units of mass per volume.

NOTE 1 The rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

NOTE 2 The symbol Q may be subscripted to designate the volume rate of flow occurring at any other observed point.

NOTE 3 In the quantities numbered 3.1.3.2 to 3.1.3.7, reference to “rate of flow” may be replaced by “mass rate of flow” in both the quantity and definitions.

3.1.3.2.1
optimum rate of flow
Q_{opt}
rate of flow at the point of best efficiency

NOTE The optimum rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.2
rated flow
Q_r
rate of flow at the guarantee point, taking into account any necessary margin

NOTE The rated flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.3
normal flow
Q_n
rate of flow at which usual operation is expected

NOTE The normal flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.4
maximum flow
Q_{max}
greatest rate of flow that is expected at operating conditions

NOTE The maximum flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.5
minimum flow
Q_{min}
smallest rate of flow that is expected at operating conditions

NOTE The minimum flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.6
maximum allowable flow
$Q_{max,ad}$
greatest rate of flow that the pump can be expected to deliver continuously without risk of internal damage when operated at the rated speed and on the liquid for which it was supplied

NOTE The maximum allowable flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.7
minimum allowable flow
$Q_{min,ad}$
smallest rate of flow that the pump can be expected to deliver continuously without risk of internal damage when operated at the rated speed and on the liquid for which it was supplied

NOTE The minimum allowable flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.7.1
minimum allowable stable flow
$Q_{min,ad,st}$
lowest flow at which the pump can operate without exceeding the noise and vibration limits imposed in the order

NOTE The minimum allowable stable flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.2.7.2
minimum allowable thermal flow
$Q_{min,ad,therm}$
lowest flow at which the pump can operate without its operation being impaired by the temperature rise of the pumped liquid

NOTE 1 The minimum allowable thermal flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

NOTE 2 The user should specify the liquid properties, such as the specific heat and vapour pressure, according to the temperature per degrees Celsius.

3.1.3.3
balancing rate of flow
Q_B
rate of flow that is extracted to activate a balance device

NOTE The balancing rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.4
leakage rate of flow
Q_L
rate of flow leaking from shaft seals

NOTE The leakage rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.5
inlet rate of flow
Q_1
rate of flow passing the inlet area of the pump from the inlet side of the installation

NOTE The inlet rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.6
outlet rate of flow
Q_2
rate of flow passing the outlet area of the pump into the outlet side of the installation

NOTE The outlet rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.3.7
intermediate take-off rate of flow
$Q_{3,4,...}$
rate of flow passing through one or more intermediate take-off points

NOTE The intermediate take-off rate of flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour, litres per second.

3.1.4 Height

NOTE These definitions refer to the physical position of the observed point.

3.1.4.1
reference plane
any horizontal plane that can be used as the datum for height measurement

NOTE 1 A physical reference plane is more practical than an imaginary one for measurement purposes.

NOTE 2 The manufacturer should indicate the position of the reference plane as defined with respect to precise reference points on the exterior of the pump.

3.1.4.2
height
z
elevation of an observed point above a reference plane

NOTE 1 The height is expressed in units of metres.

NOTE 2 The height is positive if the observed point is higher than the reference plane.

NOTE 3 The symbol z may be subscripted to designate the height of any observed point.

3.1.4.3
height of the inlet connection
z_1
height of the centre of the inlet connection of the pump

NOTE The height of the inlet connection is expressed in units of metres.

3.1.4.4
height of the outlet connection
z_2
height of the centre of the outlet connection of the pump

NOTE The height of the outlet connection is expressed in units of metres.

3.1.4.5
height of the inlet-side measuring point
z_1'
height of the manometer connection in the pipe at the inlet side of the pump

NOTE 1 The height of the inlet-side measuring point is expressed in units of metres.

NOTE 2 Where an annular pressure chamber or several pressure tappings in the circumference of the pipe are used, the height shall be taken at the centre of the measuring profile.

3.1.4.6
height of the outlet-side measuring point

z_2'

height of the manometer connection in the pipe at the outlet side of the pump

NOTE 1 The height of the outlet-side measuring point is expressed in units of metres.

NOTE 2 Where an annular pressure chamber or several pressure tappings in the circumference of the pipe are used, the height shall be taken at the centre of the measuring profile.

3.1.4.7
height of the inlet side of the installation

z_{A1}

height of the liquid level on the inlet side of the installation or of the centre of the inlet manifold

See Figure A.1.

NOTE The height of the inlet side of the installation is expressed in units of metres.

3.1.4.8
height of the outlet side of the installation

z_{A2}

height of the liquid level on the outlet side of the installation or of the centre of the outlet manifold

See Figure A.1.

NOTE The height of the outlet side of the installation is expressed in units of metres.

3.1.4.9
height of the inlet manometer

z_{1M}

height of the zero or centre position of the inlet manometer or other point, as defined by the manometer calibration

See Figure A.1.

NOTE The height of the inlet manometer is expressed in units of metres.

3.1.4.10
height of the outlet manometer

z_{2M}

height of the zero or centre position of the outlet manometer or other point, as defined by the manometer calibration

See Figure A.1.

NOTE The height of the outlet manometer is expressed in units of metres.

3.1.4.11
level difference

$z_{x\text{-}x}$

difference in the height between two points

NOTE 1 The level difference is expressed in units of metres.

NOTE 2 The level difference is positive if the value at the point shown after the hyphen is greater than the value at the point shown before the hyphen.

3.1.5 Heads

NOTE These definitions refer to the energy of the fluid.

3.1.5.1
head
H
energy per unit mass of fluid divided by gravitation acceleration

NOTE 1 The head is expressed in units of metres.

NOTE 2 The head is considered as the height of a column of fluid at rest exerting a pressure on its bottom surface equivalent to the energy per unit mass being acted upon by the acceleration due to gravity.

NOTE 3 The symbol *H* may also be subscripted to designate the head occurring at any observed point.

3.1.5.1.1
pressure head
$H_{\mathrm{M}x}$
head corresponding to the pressure shown on a manometer observed at point x

NOTE The pressure head is expressed in units of metres.

3.1.5.1.2
velocity head
H_U
head corresponding to the kinetic energy in the fluid observed at the point indicated by the subscript

NOTE The velocity head is expressed in units of metres.

3.1.5.1.3
total head
$H_{\mathrm{t},x}$
head observed at point x, corresponding to the sum of the height, pressure head and velocity head of the fluid at point x, as given by Equation (2):

$$H_{\mathrm{t},x} = z_x + \frac{p_x}{\rho_x g} + \frac{U_x^2}{2g} \tag{2}$$

where

p_x is the gauge pressure observed at point x;

z_x is the height of point x;

ρ_x is the density at point x;

U_x is the mean velocity at point x;

g is the acceleration due to gravity.

NOTE 1 The total head is expressed in units of metres.

NOTE 2 Atmospheric pressure at point x should be added into the above equation to convert it to absolute pressure.

3.1.5.1.3.1
installation total head
$H_{\mathrm{t,A2\text{-}1}}$
difference between the total head at the outlet side of the installation and the total head at the inlet side of the installation, as given by Equation (3):

$$H_{\mathrm{t,A2\text{-}1}} = H_{\mathrm{t,A2}} - H_{\mathrm{t,A1}} \tag{3}$$

NOTE The installation total head is expressed in units of metres.

3.1.5.1.3.2
pump total head
$H_{t,2-1}$
difference between the total head at the outlet side of the pump and the total head at the inlet side of the pump

See Figure A.1.

NOTE 1 The pump total head is expressed in units of metres.

NOTE 2 Frequently, the symbol H is used instead of $H_{t,2-1}$.

NOTE 3 The total differential head of the pump may be regarded as the useful mechanical output per unit mass of rate of flow imparted by the pump to the pumped fluid divided by the acceleration due to gravity.

NOTE 4 The equations for calculating total heads assume that pressure varies hydrostatically at the point of observation and that the compressibility of the liquid being pumped is negligible. If compressibility is significant, it is preferable to derive alternative equations.

3.1.5.1.3.3
pump unit total head
$H_{t,gr2-1}$
difference between the total head at the outlet side of the pump unit and the total head at the inlet side of the pump unit

NOTE The pump unit total head is expressed in units of metres.

3.1.5.2
static head
H_{stat}
portion of total head at an observed point in an installation that is independent of rate of flow

NOTE The static head is expressed in units of metres.

3.1.5.3
loss of head
H_{Jx-x}
difference in the head between two points

NOTE 1 The loss of head is expressed in units of metres.

NOTE 2 The loss may be expressed as total head, pressure head or velocity head.

3.1.5.4
height of the NPSH datum plane
z_D
difference between the **NPSH datum plane** (3.2.2.1) and the **reference plane** (3.1.4.1)

See Figure A.1.

NOTE The height of the NPSH datum plane is expressed in units of metres.

3.1.5.5
net positive suction head
NPSH
margin of the absolute value of the total head above the head equivalent to the vapour pressure of the liquid at the particular temperature, referred to the **NPSH datum plane** (3.2.2.1), as given by Equation (4):

$$\text{NPSH} = H_1 - z_D + \frac{p_{amb} - p_v}{\rho_1 g} \quad (4)$$

where

H_1 is the **head** (3.1.5.1) at observation point 1;

z_D is the **height of the NPSH datum plane** (3.1.5.4), expressed in metres;

p_{amb} is the **atmosphere pressure** (3.1.9.2), expressed in pascals (bar);

ρ_1 is the **density** (3.1.16.1) at observation point 1;

g is the gravitational acceleration, expressed in metres per square second.

NOTE 1 The net positive suction head, NPSH, is expressed in units of metres.

NOTE 2 The NPSH is referred to the NPSH datum plane, whereas inlet total head NPSHA is referred to the centre of the inlet branch.

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

3.1.5.5.1
net positive suction head available
NPSHA
minimum **NPSH** (3.1.5.5) available at the inlet area of the pump as determined by the conditions of the installation for a specified rate of flow

NOTE 1 The net positive suction head available, NPSHA, is expressed in units of metres.

NOTE 2 A derogation has been given to allow the use of the abbreviation NPSHA (upright and not bold) as a symbol in mathematical equations as a consequence of its well established, historical use in this manner.

3.1.5.5.2
net positive suction head required
NPSHR
minimum **NPSH** (3.1.5.5) at the pump inlet connection required to give rated or operating performance at the specified conditions

NOTE 1 The net positive suction head required, NPSHR, is expressed in units of metres.

NOTE 2 The minimum value may be determined by one of a number of different criteria, such as visible cavitation, increase of noise and vibration (due to cavitation), defined head or efficiency drop or limitation of cavitation corrosion.

NOTE 3 If the criterion used is not indicated, it should be assumed to be **NPSH3** (3.1.5.5.3).

NOTE 4 A derogation has been given to allow the use of the abbreviation NPSHR (upright and not bold) as a symbol in mathematical equations as a consequence of its well established, historical use in this manner.

3.1.5.5.3
net positive suction head required for a drop of 3 %
NPSH3
NPSH (3.1.5.5) required for a drop of 3 % in the total head of the first stage of the pump as a standard basis for use in performance curves

NOTE 1 The net positive suction head required for a drop of 3 %, NPSH3, is expressed in units of metres.

NOTE 2 A derogation has been given to allow the use of the abbreviation NPSH (upright and not bold) as a symbol in mathematical equations as a consequence of its well established, historical use in this manner.

3.1.6
specific energy
e
energy per unit mass of liquid, as given by Equation (5):

$$e = Hg_x \tag{5}$$

where

H is the height, expressed in metres;

g_x is the gravitational acceleration at point x, expressed in metres per square second.

NOTE The specific energy is expressed in units of joules per kilogram or square metres per square second.

3.1.7 Cross-sectional areas

NOTE These definitions refer to the size of flow passages.

3.1.7.1
inlet area of the pump

A_1

free cross-sectional area of the entry opening in the inlet connection of the pump

NOTE 1 The inlet area of the pump is expressed in units of square metres.

NOTE 2 In the case of pumps with no inlet connection, the inlet area should be defined by examination.

3.1.7.2
outlet area of the pump

A_2

free cross-sectional area of the orifice in the outlet connection of the pump

NOTE 1 The outlet area of the pump is expressed in units of square metres.

NOTE 2 In the case of pumps with no outlet connection, the outlet area should be defined by examination.

NOTE 3 For pipe casing, submerged and other similar pumps with an ascending pipe-line as part of the pump, the cross-sectional area of the pipeline may be stipulated as the outlet area of the pump.

3.1.7.3
inlet area of the installation

A_{A1}

free cross-sectional area at a mutually agreed section of the inlet side of the installation where the area, height and pressure are known

NOTE The inlet area of the installation is expressed in units of square metres.

3.1.7.4
outlet area of the installation

A_{A2}

free cross-sectional area at a mutually agreed section of the outlet side of the installation where the area, height and pressure are known

NOTE The outlet area of the installation is expressed in units of square metres.

3.1.8 Velocity

NOTE These definitions refer to the speed of movement of liquid.

3.1.8.1
mean velocity at point x

U_x

rate of flow divided by the channel cross-section at point x, as given by Equation (6):

$$U_x = \frac{Q_x}{A_x} \quad (6)$$

NOTE The mean velocity at point x is expressed in units of metres per second.

3.1.8.2
mean velocity at inlet
U_1
rate of flow at pump inlet connection divided by the inlet area of the pump, as given by Equation (7):

$$U_1 = \frac{Q_1}{A_1} \tag{7}$$

NOTE The mean velocity at the inlet is expressed in units of metres per second.

3.1.8.3
mean velocity at outlet
U_2
rate of flow at pump outlet connection divided by the outlet area of the pump, as given by Equation (8):

$$U_2 = \frac{Q_2}{A_2} \tag{8}$$

NOTE The mean velocity at the outlet is expressed in units of metres per second.

3.1.8.4
mean velocity at the inlet area of the installation
U_{A1}
rate of flow at the inlet area of the installation divided by the inlet area of the installation

NOTE The mean velocity at the inlet area of the installation is expressed in units of metres per second.

3.1.8.5
mean velocity at the outlet area of the installation
U_{A2}
rate of flow at the outlet area of the installation divided by the outlet area of the installation

NOTE The mean velocity at the outlet area of the installation is expressed in units of metres per second.

3.1.8.6
local velocity
U_x
velocity existing at an observed point x in the hydraulic path carrying all or part of the rate of flow

NOTE The local velocity is expressed in units of metres per second.

3.1.9 Pressure

NOTE 1 These definitions refer to the internal force developed in the liquid.

NOTE 2 All pressures in this International Standard are gauge pressures read from a manometer or other pressure-sensing instrument, except atmospheric pressure and the vapour pressure of the liquid, which are expressed as absolute pressures.

3.1.9.1
pressure at point x
p_x
force per unit area exerted at the observed point x

NOTE The pressure at point x is expressed in units of pascal (bar).

3.1.9.2
atmospheric pressure
p_{amb}
mean absolute pressure of the atmosphere measured at the place of installation of the pump

NOTE The atmospheric pressure is expressed in units of pascal (bar).

3.1.9.3
vapour pressure of the pumped fluid
p_v
absolute pressure at which the liquid vapourizes corresponding to the temperature of the liquid

NOTE The vapour pressure of the pumped fluid is expressed in units of pascal (bar).

3.1.9.4
inlet pressure of the pump
p_1
pressure acting at the inlet area of the pump

NOTE The inlet pressure of the pump is expressed in units of pascal (bar).

3.1.9.4.1
maximum allowable inlet pressure
$p_{1,max,ad}$
highest value of inlet pressure at which the pump or component is capable of functioning on the basis of the materials used

NOTE The maximum allowable inlet pressure is expressed in units of pascal (bar).

3.1.9.4.2
maximum inlet pressure
$p_{1,max,op}$
highest inlet pressure to which the pump is subjected during operation

See Figure A.3.

NOTE The maximum inlet pressure is expressed in units of pascal (bar).

3.1.9.4.3
rated inlet pressure
$p_{1,r}$
inlet pressure of the operating conditions at the guarantee point

NOTE The rated inlet pressure is expressed in units of pascal (bar).

3.1.9.5
outlet pressure of the pump
p_2
pressure acting at the outlet area of the pump

NOTE The outlet pressure of the pump is expressed in units of pascal (bar).

3.1.9.5.1
maximum outlet pressure
$p_{2,max}$
sum of maximum inlet pressure plus maximum differential pressure derived from the furnished impeller when operating at rated conditions and density

See Figure A.3.

NOTE The maximum outlet pressure is expressed in units of pascal (bar).

3.1.9.5.2
rated outlet pressure
$p_{2,r}$
outlet pressure of the pump at the guarantee point with rated flow, rated speed, rated inlet pressure and density

See Figure A.3.

NOTE The rated outlet pressure is expressed in units of pascal (bar).

3.1.9.6 Differential pressure

3.1.9.6.1
differential pressure

$p_{1\text{-}2}$
⟨actual⟩ gain in total head between the pump inlet and pump outlet

NOTE The differential pressure is expressed in units of pascal (bar).

3.1.9.6.2
rated differential pressure

$p_{1\text{-}2,\mathrm{r}}$
differential pressure for the operating conditions at the guarantee point

NOTE The rated differential pressure is expressed in units of pascal (bar).

3.1.9.7
gauge pressure at point x

$p_{x,\mathrm{man}}$
reading on a pressure-measuring instrument attached to an observed point x

NOTE The gauge pressure at point x is expressed in units of pascal (bar).

3.1.9.8
inlet pressure of the installation

p_{A1}
pressure measured at the inlet area of the installation

NOTE The inlet pressure of the installation is expressed in units of pascal (bar).

3.1.9.9
outlet pressure of the installation

p_{A2}
pressure measured at the outlet area of the installation

NOTE The outlet pressure of the installation is expressed in units of pascal (bar).

3.1.9.10
maximum allowable working pressure

$p_{\mathrm{max,ad}}$
pressure for a component on the basis of materials used and on the basis of calculation rules at the specified operating temperature

See Figure A.2.

NOTE The maximum allowable working pressure is expressed in units of pascal (bar).

3.1.9.11
maximum allowable casing working pressure

$p_{\mathrm{max,ad,C}}$
greatest outlet pressure at the specified operating temperature at which the pump casing can be used

NOTE 1 The maximum allowable casing working pressure is expressed in units of pascal (bar).

NOTE 2 This pressure should be equal to, or greater than, the maximum outlet pressure.

See Figure A.2.

3.1.9.12
maximum dynamic sealing pressure
$p_{S,max,op}$
highest pressure expected at the shaft seals during any specified operating condition and during startup and shutdown

NOTE 1 The maximum dynamic sealing pressure is expressed in units of pascal (bar).

NOTE 2 In determining this pressure, consideration should be given to the maximum inlet pressure, circulation or injection (flush) pressure and the effect of internal clearance changes.

3.1.9.13
maximum static sealing pressure
$p_{S,max,stat}$
highest pressure, excluding hydrostatic testing, to which the seal can be subjected while the pump is shut down

NOTE The maximum static sealing pressure is expressed in units of pascal (bar).

3.1.9.14
hydrostatic test pressure
p_{test}
gauge pressure to which a part, component or pump is subjected for the purpose of strength or leak testing

NOTE The hydrostatic test pressure is expressed in units of pascal (bar).

3.1.9.15
basic design pressure
p_b
pressure derived from the permitted stress at 20 °C of the material used for the pressure-containing parts

NOTE The basic design pressure is expressed in units of pascal (bar).

3.1.10 Temperature

3.1.10.1
maximum allowable temperature
$\theta_{max,ad}$
highest allowable continuous temperature for which the equipment (or any part to which the term refers) is suitable when handling the specified operating fluid at the specified operating pressure

NOTE The maximum allowable temperature is expressed in units of degrees Celsius.

3.1.10.2
allowable temperature range of the pump
temperature range from minimum through maximum allowable continuous temperature for which the equipment (or any part to which the term refers) is suitable when handling the specified operating fluid at the specified operating pressure

NOTE The allowable temperature range of the pump is expressed in units of degrees Celsius.

3.1.11 Power

NOTE These definitions refer to the rate of energy transfer.

3.1.11.1
pump power output
P_u
useful mechanical power transferred to the liquid during its passage through the pump, as given by Equation (9):

$$P_u = \rho QgH \tag{9}$$

NOTE The pump power output is expressed in units of watts or kilowatts.

3.1.11.2
pump power input
P
power transmitted to the pump by its driver

NOTE The pump power input is expressed in units of watts or kilowatts.

3.1.11.2.1
pump rated power input
P_r
power required by the pump at the rated conditions

NOTE The pump rated power input is expressed in units of watts or kilowatts.

3.1.11.3
driver power input
P_{mot}
power absorbed by the pump driver

NOTE 1 The driver power input is expressed in units of watts or kilowatts.

NOTE 2 It is also common practice to use P_1 instead of P_{mot}. In these cases the subscript “1” refers to the electrical input to the motor rather than to the inlet of the pump.

3.1.11.4
driver rated power output
$P_{mot,u,r}$
continuous driver power output permitted under defined conditions

NOTE The driver rated power output is expressed in units of watts or kilowatts.

3.1.11.5
pump mechanical power loss
$P_{J,ab}$
power absorbed by friction in bearings and shaft seal at given operating conditions of the pump

NOTE The pump mechanical power loss is expressed in units of watts or kilowatts.

3.1.12 Efficiency

NOTE These definitions refer to energy loss.

3.1.12.1
pump efficiency
η
proportion of the pump power input, P, delivered as pump power output, P_u, at given operating conditions, as given by Equation (10):

$$\eta = \frac{P_u}{P} \tag{10}$$

3.1.12.1.1
pump best efficiency
η_{max}
η_{opt}
η_{BEP}
greatest value of pump efficiency obtained at a given speed pumping for a given liquid

3.1.12.2
mechanical efficiency
η_m
proportion of the pump power input, P, available after satisfying the mechanical power losses, $P_{J,ab}$, at given operating conditions, as shown by Equation (11):

$$\eta_m = \frac{P - P_{J,ab}}{P} \quad (11)$$

3.1.12.3
internal efficiency
η_{int}
proportion of the pump power input, P, which is delivered as pump power output, P_u, after satisfying the mechanical power losses

3.1.12.4
hydraulic efficiency
η_h
proportion of pump power input, P, which is delivered as pump power output, P_u, after satisfying the mechanical losses, losses resulting from friction due to the relative motion of internal surfaces and internal leakage

3.1.12.5
motor efficiency
η_{mot}
proportion of the driver power input, P_{mot}, delivered as pump power input, $P_{mot,\,u}$, as given by Equation (12):

$$\eta_{mot} = \frac{P_{mot,\,u}}{P_{mot}} \quad (12)$$

3.1.12.6
overall efficiency
η_{gr}
proportion of the driver power input, P_{mot}, delivered as pump power output, P_u, as given by Equation (13):

$$\eta_{gr} = \frac{P_u}{P_{mot}} \quad (13)$$

3.1.13 Performance

NOTE These definitions refer to the relationship between quantities describing pump operation.

3.1.13.1
duty point
target values of the total head or pressure of the pump and the rate of flow for which a pump is designed or selected

3.1.13.2
guarantee point
operating performance of the pump that the supplier guarantees to be achieved under specified conditions

NOTE The guarantee point may be defined as

— pump total head or pressure at a specified rate of flow,

— rate of flow at a specified pump total head or pressure,

— pump or motor power input,

— pump or overall efficiency,

— NPHSR or NPIPR,

— other points on the pump $H(Q)$ curve for rotodynamic pumps.

3.1.13.3
allowable operating range
range of flows, heads or pressures at the specified operating conditions of the pump supplied as limited by cavitation, heating, vibration, noise, shaft deflection and other similar criteria

NOTE This range is defined by the manufacturer. The upper and lower limits of the range are denoted by maximum or minimum continuous flow.

3.1.13.4
pump power input curve
relationship between the pump power input and the rate of flow at given operating conditions of speed and liquid

3.1.13.5
pump efficiency curve
relationship between the pump efficiency and the rate of flow at given operating conditions of speed and liquid

3.1.13.6
pump NPSHR curve
pump NPSH curve
relationship between the net positive suction head required and the rate of flow at given operating conditions of speed and liquid

3.1.13.7
installation NPSHA curve
installation NPSH curve
relationship between the net positive suction head available and the rate of flow at given operating conditions for a given liquid

3.1.14 Rotation speed

NOTE These definitions refer to the rotational speed and direction.

3.1.14.1
speed
n
number of rotations or movements made by the shaft, coupling or impeller in unit time

NOTE The speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.1.14.2
maximum allowable continuous speed
$n_{\mathrm{max,ad}}$
highest speed for continuous operation recommended by the manufacturer

NOTE The maximum allwable continuous speed is expressed in units of reciprocal minutes or reciprocal seconds. According to ISO 1000, the designations “revolution per minute” (r/min) and “revolution per second” (r/s) are also widely used.

3.1.14.3
minimum allowable continuous speed
$n_{\mathrm{min,ad}}$
lowest speed for continuous operation recommended by the manufacturer

NOTE The minimum allowable continuous speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.1.14.4
rated speed
n_{r}
number of revolutions per unit of time of the pump required to meet the rated conditions

NOTE The rated speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.1.14.5
trip speed
n_{trip}
speed at which the independent emergency overspeed devices operate to shut down a prime mover

NOTE The trip speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.1.14.6
clockwise rotation
CW
direction of rotation in which the shaft is seen to be turning in a clockwise direction when viewing the drive end of the shaft

3.1.14.7
counter-clockwise rotation
CCW
direction of rotation in which the shaft is seen to be turning in an anticlockwise direction, when viewing the drive end of the shaft

3.1.15 Forces and loads

NOTE These definitions refer to the thrusts on an installed pump and installation.

3.1.15.1
connection load
loads imposed on the inlet and outlet of a pump or pump set by the pipes connected to them

3.1.15.2
force
F_X, F_Y, F_Z, F_R
value, direction and effect at the inlet

NOTE Force is expressed in units of newtons.

3.1.15.3
moment
M_X, M_Y, M_Z, M_R
outlet branches of loads imposed by the connected pipework

NOTE Moment is expressed in units of newton-metres.

3.1.15.4
axial load of pump rotor
F_{ax}
residual thrust acting through the shaft, derived from hydraulic or mechanical forces, where

— + is the direction towards the drive end of the shaft;

— − is the direction away from the drive end of the shaft.

NOTE The axial load of the pump rotor is expressed in units of newtons.

3.1.15.4.1
design axial load
$F_{ax,d}$
residual axial thrust on the pump rotor on which the thrust-bearing selection is based

NOTE The design axial load is expressed in units of newtons.

3.1.15.4.2
maximum axial load
$F_{ax,max}$
greatest value of the residual axial thrust on the pump rotor resulting from operating the pump at any condition within its allowable operating range

NOTE The maximum axial load is expressed in units of newtons.

3.1.15.5
radial load of pump rotor
F_{rad}
residual force acting at right angles to the line of the shaft and derived from hydraulic forces

NOTE The radial load of the pump rotor is expressed in units of newtons.

3.1.15.5.1
design radial load
$F_{rad,d}$
radial load of the pump rotor for which the bearing system is selected

NOTE The design radial load is expressed in units of newtons.

3.1.15.5.2
maximum radial load
$F_{rad,max}$
greatest radial load of the pump rotor resulting from operating the pump at any condition within its allowable operating range

NOTE The maximum radial load is expressed in units of newtons.

3.1.15.6
shaft deflection
displacement of a shaft from its geometric centre in response to the radial hydraulic forces

NOTE 1 The shaft deflection is expressed in units of micrometres.

NOTE 2 Shaft deflection does not include shaft movement caused by tilting within the bearing clearances, bending caused by impeller unbalance or shaft runout.

3.1.16 Pumped liquid characteristics

NOTE These definitions refer to the qualities of the liquid affecting the pump performance.

3.1.16.1
density
ρ
mass per unit volume at a stated temperature

NOTE Density is expressed in units of kilograms per cubic metre.

3.1.16.2
kinematic viscosity
υ
ratio of the dynamic viscosity to the density of the pumped liquid

NOTE Kinematic viscosity is expressed in units of square metres per second.

3.1.16.3
dynamic viscosity
μ
ratio of the shear stress to the shear velocity acting in a liquid subjected to a planar shear motion

NOTE Dynamic viscosity is expressed in units of pascal-seconds or newton-seconds per square metre.

3.1.16.4
mixture
combination of two or more substances remaining separate, yet behaving as a single liquid for pumping

3.1.16.5
gas content
proportion of gaseous substance in the liquid to be pumped, either as a contaminant or as vapour from the main body of liquid

NOTE Gas content is expressed in units of mass percent or volume percent.

3.1.16.6
solids content
proportion of solids contained in the liquid to be pumped, either as a contaminant or as a deliberate useful burden or suspension

NOTE Solids content is expressed in units of mass percent.

3.1.16.7
multi-phase
comprising a liquid together with substances in solid or gaseous states, whether due to deliberate addition or change of state due to changed conditions

NOTE Other liquid characteristics, e.g. operating temperature, **vapour pressure** (3.1.9.3), etc., may also affect the pump performance.

3.1.17 Miscellaneous terms

NOTE These definitions refer to the parts of the pump and installation.

3.1.17.1
pump liquid
liquid or fluid that is handled by the pump at specified operating conditions

3.1.17.2
liquid pump
machine for raising liquids from a low to a high energy level, for instance

— by the effect of a force on the pumping medium,

— by transferring mechanical work to the pumping medium,

— by impulse exchange,

— by utilizing the energy of a moving column of liquid when suddenly arrested,

— by making use of the viscosity of the pumped fluid,

— by the action of a magnetic field on the medium to be pumped.

3.1.17.3
parallel operation
operating pumps with the inlet connections interconnected and the outlet connections interconnected to permit simultaneous operation in the same system, thereby giving an increased rate of flow

3.1.17.4
series operation
operating pumps with the outlet connection of the first pump connected to the inlet connection of the next pump to permit simultaneous operation in the same system, thereby giving higher outlet pressure

3.1.17.5
corrosion allowance
portion of the wall thickness of the parts wetted by the pumped liquid in excess of the theoretical thickness required to withstand the pressure limits by the maximum allowable working pressure

3.1.17.6
axial split
casing joints that are parallel to the shaft centreline

3.1.17.7
radial split
casing joints that are transverse to the shaft centreline

3.1.17.8
shaft runout
total radial deviation indicated by a device measuring shaft position relative to the bearing housing as the shaft is rotated manually in its bearings with the shaft in the horizontal position

3.1.17.9
shaft stiffness
comparative ability of shafts to resist bending loads

3.1.17.10
face runout
total axial deviation indicated at the outer radial face of the shaft seal casing by a device attached to, and rotated with, the shaft when the shaft is rotated manually in its bearings in the horizontal position

NOTE The radial face is that which determines the alignment of a seal component.

3.1.17.11
seal flush
circulation
return of pumped liquid from high-pressure area to seal cavity

NOTE Seal flush can be provided by external piping or internal passage and is used to remove heat generated at the seal, to maintain positive pressure in the seal cavity or to improve the working environment for the seal. In some cases, it can be desirable to circulate from the seal cavity to a lower-pressure area (for example the inlet).

3.1.17.12
injection flush
introduction of an appropriate (clean, compatible, etc.) liquid into the seal cavity from an external source and then into the pumped liquid

3.1.17.13
barrier liquid
liquid introduced between pressurized dual (double) mechanical seals to completely isolate the pump process liquid from the environment

NOTE The pressure of the barrier liquid is always higher than the process pressure being sealed.

3.1.17.14
buffer liquid
liquid used as a lubricant or buffer between unpressurized dual (tandem) mechanical seals

NOTE The liquid is always at a pressure lower than the process pressure being sealed.

3.1.17.15
quenching
continuous or intermittent introduction of an appropriate (clean, compatible, etc.) fluid on the atmospheric side of the main shaft seal

NOTE Quenching is used to exclude air or moisture, prevent or clear deposits (including ice), lubricate an auxiliary seal, snuff out fire, dilute, heat or cool leakage.

3.1.17.16
throttle bush
close-clearance, restrictive bushing around the shaft (or sleeve) at the outboard end of a mechanical seal, to reduce leakage in case of seal failure

3.1.17.17
auxiliary connections
connections provided for flush, bypass, pressure balance, or other similar purposes

NOTE They should not be confused with intermediate or supplementary outlet connections.

3.1.17.18
canned motor pump
canned rotor
motor **rotor** (3.2.9.9) immersed in the pumped or other liquid and encased in a thin wall separating it from the stator

3.1.17.19
hydrodynamic bearing
bearing whose surface is oriented to another surface such that relative motion forms an oil wedge to support the load without metal-to-metal contact

3.1.17.19.1
hydrodynamic radial bearing
bearing of sleeve-journal- or tilting-shoe-type construction

3.1.17.19.2
hydrodynamic thrust bearing
bearing of multiple-segment- or tilting-shoe-type construction

3.1.17.20
product lubrication
arrangement in which the bearings are submerged in, and lubricated by, the pumped liquid

3.1.17.21
submersible pump
pump unit (3.1.1.2) designed to operate fully submerged in the pumped liquid

3.1.17.22
submergible pump
pump (3.1.1.1) designed to continue to operate when temporarily covered by liquid which may or may not be the pumped liquid

3.1.17.23
driver
machine supplying mechanical energy

3.1.17.24
coupling
link by which energy is transferred between the driver and the pump

NOTE The energy transmission can be mechanic, hydraulic or magnetic.

3.1.17.24.1
coupling service factor
factor which is multiplied by the nominal torque of the driver in order to get a fictitious torque that makes due allowance for cyclic torque fluctuations from the pump and/or its driver and, therefore, ensures a satisfactory coupling life

3.1.17.25
part
piece of equipment that, when assembled together with others, makes a pump

3.1.17.26
sub-assembly
assembly of parts put together for convenience, which might or might not fulfil a discrete function

3.1.17.27
component
assembly of parts put together to fulfil a specific, identifiable function independently or in combination with other parts/components

3.1.17.28
standby service
idle or idling piece of equipment that is capable of immediate automatic or manual startup and continuous operation

3.1.17.29
standby pumps
pumps additional to the duty need, installed to provide immediate cover in the event of failure of the main pumps

3.1.17.30
pressure casing
pressure-containing part that acts as a barrier between process or motive liquid and the atmosphere

3.2 Special terms for rotodynamic pumps

3.2.1 Rates of flow

3.2.1.1
minimum continuous stable flow
$Q_{\mathrm{st,min}}$
lowest flow at which the pump can be operated without it adversely affecting its performance in terms of life expectancy, noise and vibrations

NOTE The minimum continuous stable flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour or litres per second.

3.2.1.2
minimum continuous thermal flow
$Q_{\mathrm{therm,min}}$
lowest flow at which the pump can operate without its operation being impaired by the temperature rise of the pumped liquid

NOTE 1 The minimum continuous thermal flow is expressed in units of cubic metres per hour, cubic metres per second, litres per hour or litres per second.

NOTE 2 The user should specify the liquid properties of specific heat and change of vapour pressure per degree Celsius.

3.2.1.3
allowable operating range
range of flows or heads at the specified operating conditions of the pump supplied as limited by cavitation, heating, vibration, noise, shaft deflection and other similar phenomena

NOTE 1 The allowable operating range is expressed in units of cubic metres per hour, cubic metres per second, litres per hour or litres per second.

NOTE 2 The upper and lower limits of the range are denoted by maximum and minimum continuous flow as specified by the manufacturer.

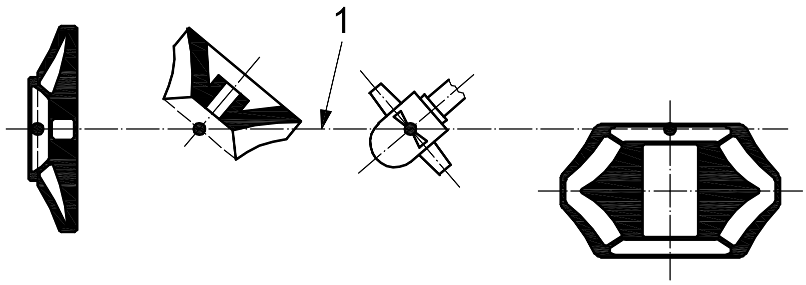
3.2.2 Heights

3.2.2.1
NPSH datum plane
horizontal plane through the centre of the circle described by the external points of the entrance edges of the impeller blades; in the first stage in the case of multistage pumps

See Figure 1.

NOTE 1 In the case of double inlet pumps with vertical or inclined axis, it is the plane through the higher centre.

NOTE 2 The manufacturer should indicate the position of this plane with respect to precise reference points on the pump.



Key

1 NPSH datum plane

Figure 1 — NPSH datum plane

3.2.3 Power

3.2.3.1
optimum pump power input
P_{opt}
pump power input at the rate of flow corresponding to the best efficiency

NOTE The optimum pump power input is expressed in units of kilowatts or watts.

3.2.3.2
shut-off pump power input
P_0
pump power input at zero rate of flow

NOTE The shut-off pump power input is expressed in units of kilowatts or watts.

3.2.3.3
maximum pump power input
P_{max}
highest value of the pump power input at any rate of flow at any allowable operating condition

NOTE The maximum pump power input is expressed in units of kilowatts or watts.

3.2.4 Heads

3.2.4.1
optimum head
H_{opt}
total head developed by the pump at a rate of flow corresponding to the best efficiency

NOTE The optimum head is expressed in units of metres.

3.2.4.2
shut-off head
H_0
total head developed by the pump in a zero rate of flow

NOTE The shut-off head is expressed in units of metres.

3.2.4.3
head at peak point
H_p
highest total head developed by a pump when this does not occur at a zero rate of flow

NOTE The head at peak point is expressed in units of metres.

3.2.4.4
maximum head
H_{max}
highest total head developed by a pump at any rate of flow

NOTE 1 The maximum head is expressed in units of metres.

NOTE 2 H_{max} is equal to either H_0 or H_p depending upon the pump $H(Q)$ curve.

3.2.4.5
net positive suction head 3 %
NPSH3
See 3.1.5.5.3.

3.2.5 Cross-sectional area

3.2.5.1
throat area
A_{min}
free cross-sectional area of the exit channel(s) from the casing volute

NOTE The throat area is expressed in units of square metres.

3.2.6 Velocity, speed and rotation

3.2.6.1
mean velocity at the throat
U_{thr}
rate of flow passing through the exit from the volute divided by the throat area, as given by Equation (14):

$$U_{thr} = \frac{Q_2}{A_{min}} \quad (14)$$

NOTE The mean velocity at the throat is expressed in units of metres per second.

3.2.6.2
critical speed
n_c
speed of rotation at which the lateral natural frequency of vibration of the rotating parts corresponds to the frequency of rotation

NOTE 1 The critical speed is expressed in units of reciprocal minutes or reciprocal seconds. According to ISO 1000, the designations “revolution per minute” (r/min) and “revolution per second” (r/s) are also widely used.

NOTE 2 The pumps are concerned with actual critical speeds rather than various calculated values in lateral vibration and in torsional oscillation.

3.2.6.3
dry critical speed
$n_{c,dry}$
rotor resonant frequency calculated assuming that the rotor is supported only at its bearings and that the bearings are of infinitive stiffness

NOTE The dry critical speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.2.6.4
wet critical speed
$n_{c,wet}$
rotor resonant frequency calculated considering the additional support and damping produced by the action of the pumped liquid within internal running clearances at the operating conditions and allowing for flexibility and damping within the bearings

NOTE The wet critical speed is expressed in units of reciprocal minutes or reciprocal seconds.

3.2.7 Performance

3.2.7.1
pump $H(Q)$ curve
relationship between the total head of the pump and the rate of flow at given operating/rated conditions of speed and liquid

3.2.7.1.1
stable pump $H(Q)$ curve
pump $H(Q)$ curve where the maximum head and shut-off head are coincidental, and the total head declines continuously with increasing rate of flow

3.2.7.1.2
unstable pump $H(Q)$ curve
pump $H(Q)$ curve where the maximum head (peak point) and shut-off head are not coincidental, or the total head does not decline continuously with increasing rate of flow

3.2.7.2
peak point
point of highest achieved total head in an unstable pump $H(Q)$ curve

3.2.7.3
operating point
point at which a pump operates in an installation; it occurs at the intersection of the pump $H(Q)$ curve and the installation $H_A(Q)$ curve

3.2.8 Pump characterizing number

NOTE These definitions refer to the functioning of the pump.

3.2.8.1
type number

K_{num}

pure number calculated at the point of best efficiency, which is defined as given by Equation (15)

$$K_{num} = \frac{2\pi n \, Q_{opt}^{0,5}}{(g \, H_{opt})^{0,75}} \quad (15)$$

where

Q_{opt} is the volume rate of flow at the point of best efficiency (see 3.1.3.2.1), expressed in cubic metres per second;

H_{opt} is the total head developed by the pump at a rate of flow corresponding to the best efficiency (see 3.2.4.1), expressed in metres;

n rotational speed of the pump, expressed in reciprocal seconds.

NOTE 1 The type number is taken at maximum impeller diameter.

NOTE 2 See also 3.2.8.2.

3.2.8.2
specific speed

n_s

speed that characterizes a pump in terms of its speed, flow rate per impeller eye, i.e. total flow for single-flow impeller, one half flow for double-flow impeller, at the best efficiency point and head per stage at maximum impeller diameter, as given by Equation (16)

$$n_s = n \frac{Q_{opt}^{0,5}}{H_{opt}^{0,75}} \quad (16)$$

where

n is the rotational speed of the pump, expressed in reciprocal seconds;

H_{opt} is the total head developed by the pump at a rate of flow corresponding to the best efficiency (see 3.2.4.1), expressed in metres;

Q_{opt} is the volume rate of flow at the point of best efficiency (see 3.1.3.2.1), expressed in cubic metres per second.

NOTE 1 The specific speed is expressed in units of reciprocal minutes.

NOTE 2 n_s can be dimensionless if $(g \, H_{opt})^{0,75}$ is used in the denominator and coherent units are used. However, the usual practice is not to incorporate g, and to use metres, cubic metres per second and reciprocal minutes.

NOTE 3 See also 3.2.9.1.

NOTE 4 The relationship between the numerical values of K_{num} and n_s, as given by Equation (17):

$$K_{num} = \frac{n_s}{52,919} \quad (17)$$

3.2.8.3
suction-specific speed

n_{s1}

speed that characteristizes a pump's cavitation performance in terms of its speed, optimum rate of flow per impeller eye at best efficiency point and NPSH3 at best efficiency point for the first stage at maximum impeller diameter, as given by Equation (18)

$$n_{s1} = n \cdot \frac{Q_{opt}^{0,5}}{(\mathrm{NPSHR})^{0,75}} \qquad (18)$$

NOTE 1 The suction-specific speed is expressed in units of reciprocal minutes.

NOTE 2 n_{s1} can be dimensionless if $(g\ \mathrm{NPSHR})^{0,75}$ is used in the denominator and coherent units are used. However, usual practice is not to incorporate g, and to use metres, cubic metres per second and reciprocal minutes.

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

NOTE 4 The symbol "S" is sometime used instead of n_{s1}.

3.2.9 Miscellaneous terms

3.2.9.1
rotodynamic pump
machine to transfer mechanical energy through a rotating impeller to gain velocity and pressure for the pumped liquid

3.2.9.2
single-stage
⟨pump⟩ with one impeller

3.2.9.3
multistage
⟨pump⟩ with more than one impeller mounted on the same shaft and connected so as to act in series

3.2.9.4
single-flow
⟨impeller⟩ with a single-entry flow direction

3.2.9.5
double-flow
⟨impeller⟩ with a double-entry flow direction

3.2.9.6
close-coupled
⟨coupling arrangement⟩ having a motor that is supplied with a flange adaptor that mounts directly onto the casing or body of the pump, permitting the use of a single or solidly coupled shaft

3.2.9.7
double casing
type of construction for which the pressure casing is separate and distinct from the pumping elements contained in it

3.2.9.8
barrel casing
casing specially referred to a horizontal double-casing type

NOTE Inlet and outlet flanges are incorporated into the barrel casing.

3.2.9.9
rotor
assembly of all rotating parts of a rotodynamic pump

3.3 Terms specific to reciprocating and rotary positive-displacement pumps

3.3.1 Rate of flow

NOTE These definitions refer to the quantities of displaced liquid.

3.3.1.1
slip flow
Q_{sl}
flow lost internally through clearances

NOTE 1 The slip flow is expressed in units of cubic metres per hour or litres per hour.

NOTE 2 The slip flow does not include flow lost through compressibility.

3.3.1.2
geometrical flow
Q_g
product of geometrical displacement volume and speed of rotation or stroke frequency, as given by Equation (19):

$$Q_g = V_g \cdot n \qquad (19)$$

NOTE The geometrical flow is expressed in units of cubic metres per hour or litres per hour.

3.3.2 Cross-sectional areas

3.3.2.1
valve seat area
A_{vst}
total free-flow area of the valve seat(s) fitted

NOTE The valve seat area is expressed in units of square metres.

3.3.2.2
valve spill area
A_{vsp}
total free-flow spill area of the valve(s) fitted obtained by multiplying the seat bore circumference and the valve lift

NOTE The valve spill area is expressed in units of square metres.

3.3.2.3
pumping chamber area
A_{pc}
sum of all free-opening areas between the pumping elements into which fluid is drawn or discharged

NOTE The pumping chamber area is expressed in units of square metres.

3.3.3 Velocity

NOTE These definitions refer to the speed of movement.

3.3.3.1
valve seat velocity
U_{vst}
mean velocity of the flow through the valve seat at the specified operating conditions

NOTE The valve seat velocity is expressed in units of metres per second.

3.3.3.2
valve spill velocity
U_{vsp}
mean velocity of the flow through the valve spill area

NOTE The valve spill velocity is expressed in units of metres per second.

3.3.3.3
piston velocity
U_{pi}
plunger velocity
U_{pl}
average speed given by the stroke length multiplied with the number of complete pumping cycles of the piston, plunger or diaphragm per minute (stroke per minute or pump crank speed), as given by Equations (20):

$$U_{pi} = \frac{sn}{30} \text{ or } U_{pl} = \frac{sn}{30} \qquad (20)$$

where

s in the stroke length, expressed in metres;

n in the crank speed or cycles, expressed in reciprocal minutes.

NOTE The piston velocity and plunger velocity are expressed in units of metres per second.

3.3.4 Pressure

3.3.4.1
relief valve set pressure
$p_{rv,set}$
outlet pressure at which the relief valve begins to open

NOTE The relief valve set pressure is expressed in units of pascal or bar. (Bar is considered a deprecated unit.)

3.3.4.2
relief valve accumulation pressure
$p_{rv,a}$
outlet pressure at which the relief valve passes the total pump flow

NOTE The relief valve accumulation pressure is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.3
relief valve reseat pressure
$p_{rv,rs}$
outlet pressure at which the relief valve closes after passing the total pump flow

NOTE The relief valve reseat pressure is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.4
relief valve back pressure
$p_{rv,b}$
pressure at the outlet of the relief valve when the valve is closed

NOTE The relief valve back pressure is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.5
pressure pulsation
$p_{pul,x}$
pulse in the pressure at a given point x, usually quoted as a variation about a mean value

NOTE A pressure pulsation is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.6
pre-charge pressure
p_d
pressure to which the pulsation dampener is charged with gas prior to start of operation

NOTE The pre-charge pressure is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.7
net positive inlet pressure
NPIP
pressure determined at the pump inlet connection, including pump acceleration pressure minus the vapour pressure at the present temperature of the liquid

NOTE The net positive inlet pressure is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

3.3.4.8
net positive inlet pressure available
NPIPA
NPIP (3.3.4.7) minus the preliminary anticipated system acceleration pressure for the pumping system with the liquid at the rated capacity and temperature

NOTE 1 The net positive inlet pressure available is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

NOTE 2 It is the responsibility of the purchaser to determine NPIPA.

NOTE 3 Selected equipment and final piping acoustic analysis dictate as-built acceleration pressure and NPIPA.

3.3.4.9
net positive inlet pressure required
NPIPR
total inlet pressure, including pump acceleration pressure, required by the pump at the pump inlet connection, minus the liquid vapour pressure at rated temperature

See Figure A.4.

NOTE 1 The net positive inlet pressure required is expressed in units of pascals or bar. (Bar is considered a deprecated unit.)

NOTE 2 It is the responsibility of the supplier to determine NPIPR.

NOTE 3 For the NPIP values of positive displacement pumps, the reference plane is considered as the horizontal plane through the centre of the pump inlet opening.

3.3.5 Volumes

NOTE These definitions refer to the effective spaces.

3.3.5.1
clearance volume
internal volume
V_{int}
volume remaining unswept at the end of the discharge stroke

NOTE 1 The clearance volume is expressed in units of cubic metres or litres.

NOTE 2 Also known as “internal volume”.

3.3.5.2
swept volume
V_{sw}
volume traversed by a single stroke of piston, plunger or diaphragm

NOTE The swept volume is expressed in units of cubic metres or litres.

3.3.5.3
geometric displacement volume
V_g
displacement volume for one stroke or one cycle

NOTE The geometric displacement volume is expressed in units of cubic metres or litres.

3.3.6
rod load
RL
load induced in the rod at a specified point of the pumping operation cycle

NOTE The rod load is expressed in units of newtons or meganewtons.

3.3.7
volumetric efficiency
η_{1-2}
ratio of the actual pump capacity to the volume displaced per unit of time

3.3.8 Miscellaneous terms

3.3.8.1
single-acting
⟨liquid⟩ discharged only during the forward motion of the piston or plunger, that is during one half of stroke cycle or revolution

3.3.8.2
double-acting
⟨liquid⟩ discharged during both the forward and return motion of the piston, that is discharge takes place during the entire stroke cycle or revolution

3.3.8.3
simplex, duplex, triplex, multiplex
arrangement of one, two, three or more reciprocating elements delivering liquid in sequence

3.3.8.4
inboard pump
power pump where the drive connection to the piston or plunger is in the space between the crankshaft and the cylinder

3.3.8.5
outboard pump
power pump where the drive connection to the piston or plunger is at the side of the cylinder facing away from the crankshaft

3.3.8.6
manifold
assembly of ducts arranged to distribute/collect liquid between the cylinders and the single-inlet/outlet pipe-work connection

3.3.8.7
pulsation dampener
device fitted close to the inlet or outlet of a pump to reduce the magnitude of the pressure pulsations in the system

4 Comparison between specific energies and their corresponding heads

Term for specific energy	Symbol	Term for corresponding head	Symbol
of height	gz	of height	z
of velocity	$½ U^2$	of velocity head	$U^2/2g$
at point x	e_x	at point x	H_x
at pump inlet	e_1	at pump inlet	$H_{t,1}$
of pressure	p_x/ρ	of pressure	H_{Mx}
of the installation	e_A	of the installation	H_A
of the pump	e_{1-2}	of the pump total head	$H_{t,1-2}$
loss of specific energy	y_{Jx-x}	loss of head	H_{Jx-x}
net positive suction energy	NPSE	net positive suction head	NPSH

5 List of symbols and quantities

Where units in equations are given, these units shall be used. In the opposite case, care shall be taken to use consistent units (see Tables 1 and 2).

Table 1 — Alphabetical list of symbols and abbreviations

Symbol or abbreviation	Quantity	Units
A	Area	m^2
E	Energy	J
f	Frequency	s^{-1}, Hz
F	Force	N
g	Acceleration due to gravity	m/s^2
H	Head	m
K_{num}	Type number	—
k	Equivalent uniform roughness	m
l	Length	m
m	Mass	kg
M	Moment	Nm
n	Speed of rotation, stroke frequency	s^{-1}, min^{-1}, r/s, r/min, stroke/s
NPSH	Net positive suction head	m
p	Pressure	Pa (bar)
P	Power	W, kW
q	Mass rate of flow	kg/h, kg/s
Q	Volume rate of flow	m^3/h, m^3/s, l/h, l/s
Re	Reynolds number	—

Table 1 *(continued)*

Symbol or abbreviation	Quantity	Units
t	Time	s, h
tol	Tolerance, relative value	%
T	Temperature, thermodynamic	K
u	Overall uncertainty, relative value	%
U	Mean velocity	m/s
v	Local velocity	m/s
V	Volume	m^3, l
e	Specific energy	J/kg
z	Height above reference plane	m
η	Efficiency	— (often written in %)
θ	Temperature, Celsius	°C
λ	Pipe friction loss coefficient	—
μ	Dynamic viscosity	Pa·s, N·s/m^2
ρ	Density	kg/m^3
υ	Kinematic viscosity	m^2/s
ω	Angular velocity	rad/s
Additional symbols and abbreviations used for positive displacement pumps		
K	Bulk modulus	m^3/kg
Mi	Miller number	—
NPIP	Net positive inlet pressure	Pa (bar)
RL	Rod load	N, MN
s	Length of stroke	m
w	Number of pistons or other displacement elements	—
β	Compressibility	—

Table 2 — Alphabetical list of quantities

Quantity	Symbol or abbreviation	Units
Acceleration due to gravity	g [a]	m/s^2
Angular velocity	ω	rad/s
Area	A	m^2
Density	ρ	kg/m^3
Dynamic viscosity	μ	Pa·s, N·s/m^2
Efficiency	η	— (often written in %)
Energy	E	J
Equivalent uniform roughness	k	m
Force	F	N
Frequency	f	s^{-1}, Hz

Table 2 *(continued)*

Quantity	Symbol or abbreviation	Units
Head	H	m
Height above reference plane	z	m
Kinematic viscosity	υ	m^2/s
Length	l	m
Local velocity	v	m/s
Mass	m	kg
Mass rate of flow	q	kg/h, kg/s
Mean velocity	U	m/s
Moment	M	Nm
Net positive suction head	NPSH	m
Overall uncertainty, relative value	u	%
Pipe friction loss coefficient	λ	—
Power	P	W, kW
Pressure	p [b]	Pa (bar)
Reynolds number	Re	—
Specific energy	e	J/kg
Speed of rotation, stroke frequency	n	s^{-1}, min^{-1}, r/s, r/min, stroke/s
Temperature, Celsius	θ	°C
Temperature thermodynamic	T	K
Time	t	s, h
Tolerance, relative value	tol	%
Type number	K_{num}	—
Volume	V	m^3, l
Volume rate of flow	Q	m^3/h, m^3/s, l/h, l/s
Additional symbols and abbreviations used for positive displacement pumps		
Bulk modulus	K	m^3/kg
Compressibility	β	—
Length of stroke	s	m
Miller number	Mi	—
Net positive inlet pressure	NPIP	Pa (bar)
Number of pistons or other displacement elements	w	—
Rod load	RL	N, MN

[a] Acceleration due to gravity can usually be taken to be 9,81 m/s^2, but for particularly exact investigations, it can be necessary to consider local variations.

[b] All pressures as shown are gauge pressures except for atmospheric and vapour pressures, which are taken as absolute pressures:

$p_{abs} = p_x + p_{amb}$

where

p_{abs} is the absolute pressure;

p_x is the gauge pressure;

p_{amb} is the atmospheric pressure.

6 List of letters, figures and symbols used as subscripts for creating and defining symbols

The subscript can be used to denote the quantity value at a particular place, i.e. the observed point, and/or a particular set of conditions (see Table 3).

NOTE The observed point is the position to which the particular value of a quantity is referred in a definition and is indicated by a subscript.

Table 3 — List of letters, figures and symbols used as subscripts for creating and defining symbols

Subscript	Designation	Example	
0	At zero rate of flow	H_0	Shut-off head
1	Inlet side (suction)	p_1	Pressure at pump inlet
1′	Inlet-side measuring point	$p_{1'}$	Pressure at measuring point on pump inlet
2	Outlet side (discharge)	p_2	Pressure at pump outlet
2′	Outlet-side measuring point	$p_{2'}$	Pressure at measuring point on pump outlet
3, 4, ...	Intermediate take-off points	p_3	Pressure at intermediate take-off point
3′, 4′, ...	Intermediate measuring point	$p_{3'}$	Pressure at intermediate measuring point
A	Relating to the installation	p_{A1}	Pressure at measuring point on installation inlet
abs	Absolute	p_{abs}	Absolute pressure
ad	Allowable	n_{ad}	Rotating speed allowed
amb	Ambient	t_{amb}	Ambient temperature
ax	Axial	F_{ax}	Axial load of pump rotor
B	Balancing	Q_{B}	Balancing rate of flow
c	Critical	n_{c}	Critical speed
C	Relating to pump casing	$p_{\mathrm{max,ad,C}}$	Maximum allowable casing working pressure
d	Design	Q_{d}	Design flow
D	NPSH datum plane	z_{D}	Height of datum plane above reference plane
dry	Dry	$n_{\mathrm{c,dry}}$	Dry critical speed
G	Guaranteed	Q_{G}	Guarantered rate of flow
gr	Relating to pump unit	η_{gr}	Overall efficiency
h	Hydraulic	η_{h}	Hydraulic efficiency
int	Internal	η_{int}	Internal efficiency
J	Losses	H_{J}	Loss in head
L	Leak	Q_{L}	Leakage rate of flow
m	Relating to mechanical	$P_{\mathrm{J,m}}$	Pump mechanical power losses
M	Manometric	H_{M}	Head shown on gauge
max	Maximum	n_{max}	Maximum speed of rotation
min	Minimum	n_{min}	Minimum speed of rotation
mot	Relating to motor	P_{mot}	Motor power input
n	Normal	Q_{n}	Normal flow
N	Nominal	p_{N}	Basic design pressure

Table 3 *(continued)*

Subscript	Designation	Example	
op	Operating	Q_{op}	Operating flow
opt	At best efficiency duty point	H_{opt}	Optimum head
r	Rated	Q_r	Rated flow
s	Specific	n_s	Specific speed
S	Relating to shaft seal	$p_{S,max,op}$	Maximum dynamic sealing pressure
sch	Peak point of a performance curve	H_{sch}	Head at peak point
sp	Specified	n_{sp}	Specified speed
ss	Suction specific	n_{ss}	Suction-specific speed
st	Stable	$Q_{st,min}$	Minimum continuous stable flow
stat	Static	H_{stat}	Static head
t	Total	H_t	Total head at point x
T	Transmitted, torque	M_T	Transmitted moment, which is equivalent to the torque
test	Test	p_{test}	Hydrostatic test pressure
therm	Thermal	$Q_{therm,min}$	Minimum continuous thermal flow
thr	Throat	U_{thr}	Mean velocity at throat
u	Useful	P_u	Useful power output
v	Vapour	p_v	Vapour pressure
w	Working	p_w	Working pressure
x	Observed point designated	H_x	Head at observed point designated, indicated by replacing x with subscript
X	Horizontal direction	F_X	Force in horizontal direction such as along the line of shaft of a horizontal pump
Y	Vertical direction at right angle to X	M_Y	Moment of force in vertical direction at right angle to X such as along the line of shaft of a vertical pump
Z	Perpendicular direction to X and Y	F_Z	Force perpendicular to X and Y
Additional subscripts used for positive displacement pumps			
a	Accumulation	$p_{rv,a}$	Relief valve accumulation pressure
b	Back	$p_{rv,b}$	Relief valve back pressure
d	Relating to dampener	$p_{1,d}$	Inlet dampener pre-charge pressure
F	Relating to foundation	z_F	Height of foundation above reference plane
pc	Related to the pumping element	A_{pc}	Pumping chamber area(s)
g	Geometrical	Q_g	Geometrical flow rate
pi	Relating to piston	U_{pi}	Mean velocity of piston
pl	Relating to plunger	U_{pl}	Mean velocity of plunger
pr	Relating to piston rod	F_{pr}	Force in piston rod
pul	Pulsating	$p_{2,pul}$	Outlet pressure pulsations
rs	Reseat	$p_{rv,rs}$	Relief valve reseat pressure
rv	Relating to relief valve	z_{rv}	Height of relief valve

Table 3 *(continued)*

Subscript	Designation	Example	
sl	Slip	Q_{sl}	Slip flow
set	Set	$p_{rv,set}$	Relief valve set pressure
sw	Swept	V_{sw}	Swept volume
vst	Relating to valve seat	A_{vst}	Valve seat area
vsp	Relating to valve spill	A_{vsp}	Valve spill area

NOTE 1 A minus sign (–) between two subscripts indicates the difference between the values at the points identified by the subscripts but does not imply which is the greater:

$z_{1-2} = z_2 - z_1$ or $= z_1 - z_2$

NOTE 2 Throughout this International Standard, the subscript x is used to indicate where a subscript should be selected and substituted for x in order to fully identify the observed point to which the value of the quantity refers, e.g. the total head at pump inlet, $H_{t,x}$, at pump inlet, $H_{t,1}$.

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Annex A
(informative)

Figures illustrating the definitions

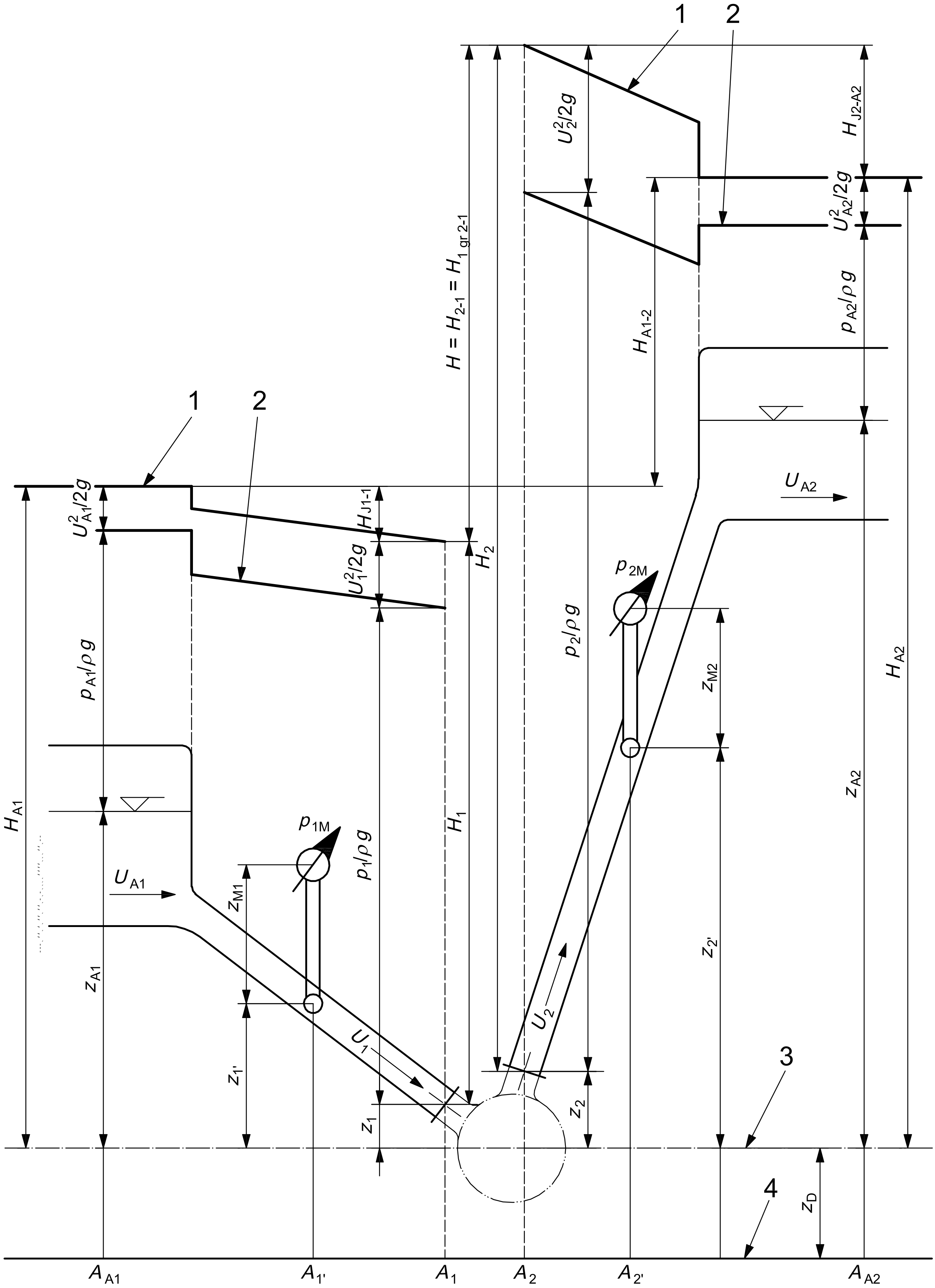


Figure A.1 — Determination of the pump total head

$$H_{2-1} = H = H_2 - H_1$$

$$H_{2-1} = H = z_2 - z_1 + \frac{p_2 - p_1}{\rho g} + \frac{v_2^2 - v_1^2}{2g}$$

$$H_{2-1} = H = z_{2'} - z_{1'} + \frac{p_{2'} - p_{1'}}{\rho g} + \frac{v_{2'}^2 - v_{1'}^2}{2g} + H_{J1'-1} + H_{J2'-2}$$

Key

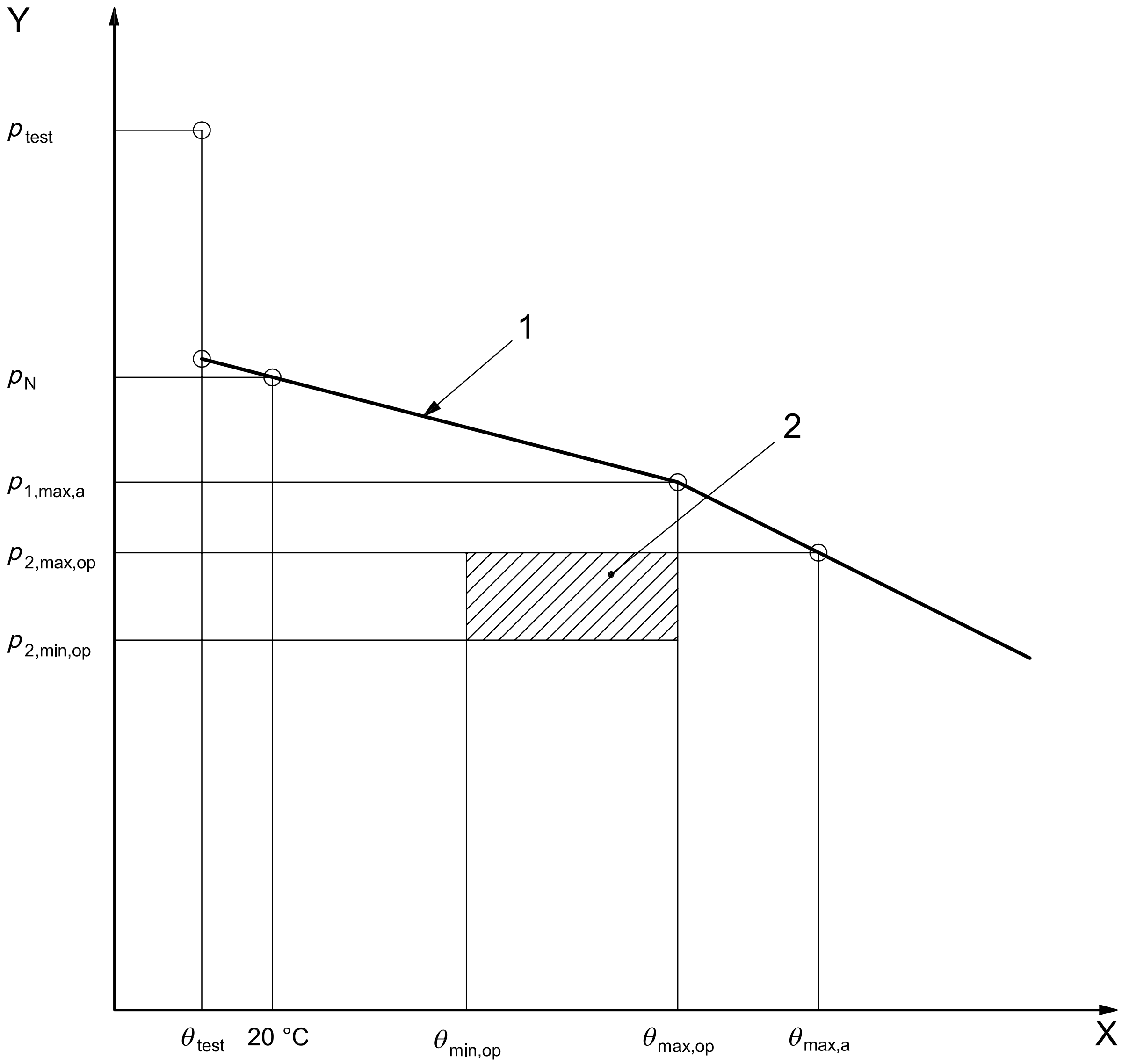
1 energy line

2 pressure line

3 NPSH datum plane

4 reference plane

Figure A.1 *(continued)*



Key

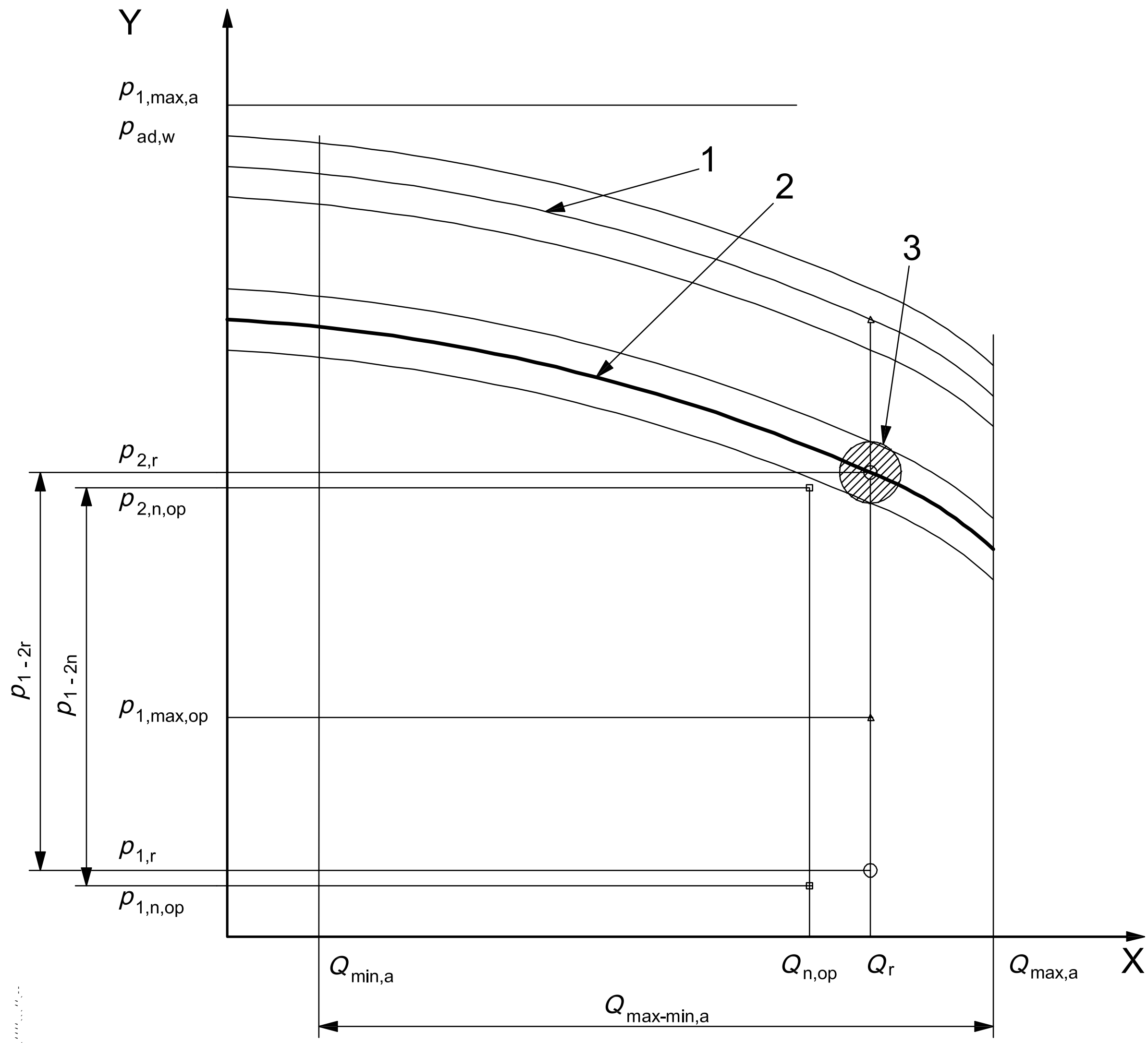
X temperature, expressed in degrees Celsius

Y pressure, expressed in pascal (bar)

1 pressure/temperature limit of a component

2 fluid operating field, including tolerances

Figure A.2 — Pressure-containing part — Pressure/temperature rating



Key

X flow, expressed in cubic metres per hour, cubic metres per second, litres per hour, litres per second

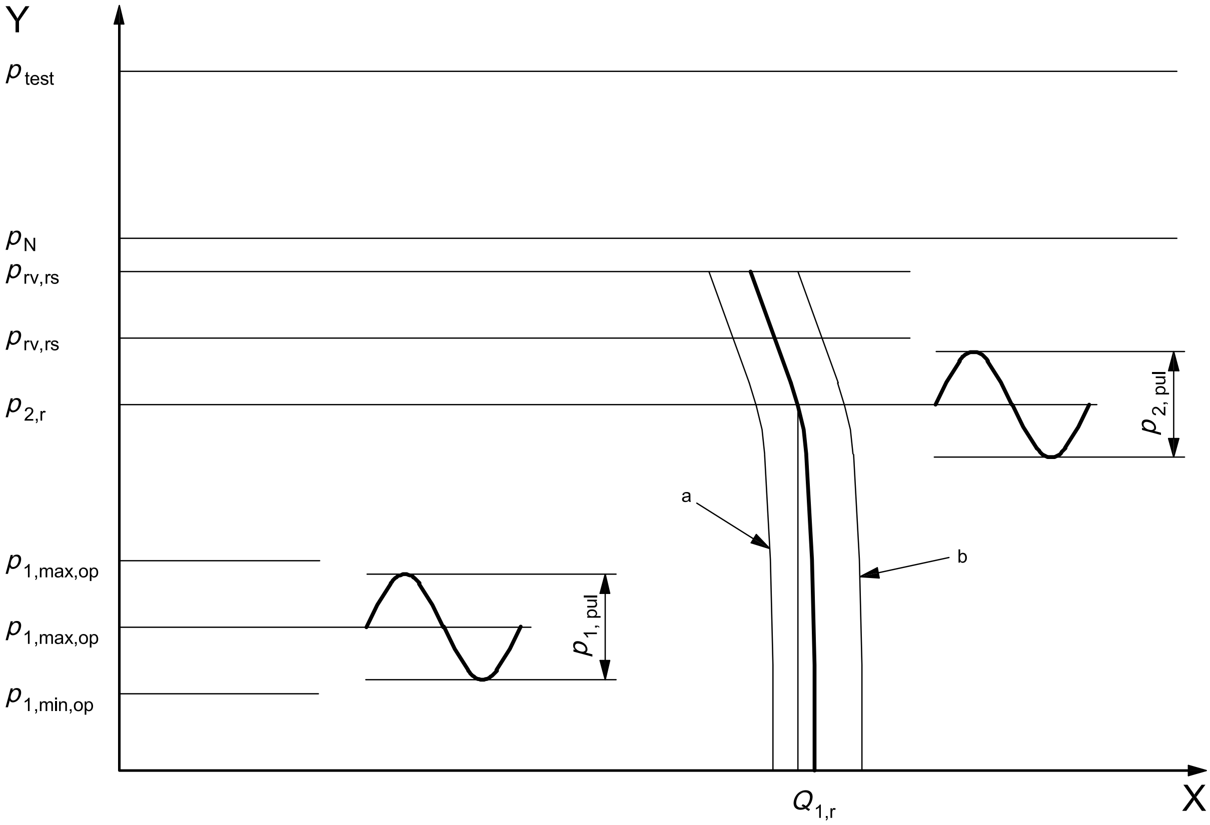
Y pressure, expressed in pascal (bar)

1 performance at maximum operating conditions

2 performance at rated conditions

3 rated point = guarantee point

Figure A.3 — Rotodynamic pump performance curve



Key

X flow, expressed in cubic metres per hour, cubic metres per second, litres per hour, litres per second

Y pressure, expressed in pascal (bar)

[a] With $P_{1,\text{min,op}}$.

[b] With $P_{1,\text{max,op}}$.

NOTE 1 The relief valve reseat pressure, $p_{\text{rv,rs}}$, can be greater or less than the rated outlet pressure, $p_{2,\text{r}}$, depending upon process requirements and the relief valve design or adjustment.

NOTE 2 For a fixed speed pump with a single-rated differential pressure, there can only be one rated flow, $Q_{1,\text{r}}$ or $Q_{2,\text{r}}$.

Figure A.4 — Positive displacement pump performance curve

Alphabetical index

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