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Nadomešča:
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Črpalke - Centrifugalne črpalke - Minimalna zahtevana učinkovitost vodnih črpalk in določevanje minimalnega indeksa učinkovitostii (MEI)

Pumps - Rotodynamic pumps - Minimum required efficiency of water pumps and determination of Minimum Efficiency Index (MEI)

Pumpen - Kreiselpumpen - Geforderte Mindesteffizienz für Wasserpumpen sowie Bestimmung des Minimum Effizienz Indexes (MEI)

Pompes - Pompes rotodynamiques - Rendement minimal requis des pompes à eau et détermination de l'Indice de rendement minimal (MEI)

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Pumps - Rotodynamic pumps - Minimum required efficiency of water pumps and determination of Minimum Efficiency Index (MEI)

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This European Standard was approved by CEN on 11 July 2021.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 16480:2021) has been prepared by Technical Committee CEN/TC 197 “Pumps”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2022, and conflicting national standards shall be withdrawn at the latest by April 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 16480:2016.

The main changes compared to the previous edition are as follows:

— the title and scope have been modified by the removal of the verification aspect throughout this document;

— Clause 3 on Terms and Definitions has been modified;

— Clause 6 on the determination of the Efficiency of a Test Pump has been updated;

— informative Annex D dealing with methods recommended for manufacturers to determine the mean values of hydraulic quantities of a size relevant for MEI has been deleted;

— informative Annex E giving a numerical example and informative Annex F describing the application of mathematical statistics on tests have been deleted;

— informative Annexes G, H and I, dealing with measurement uncertainties, the methodology of the verification procedure and the reporting of test results, respectively, have been deleted;

— the Annex ZA showing the relationship between this European Standard and the Ecodesign requirements of Commission Regulation (EU) No 547/2012 has been updated.

This document has been prepared under a Standardization Request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s) / Regulation(s).

For relationship with EU Directive(s) / Regulation(s), see informative Annex ZA, which is an integral part of this document.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Purpose and content of this document

The water pumps within the scope of this document are typically produced and sold by pump manufacturers as series of large to very large numbers. The performance characteristics of pumps of one size produced by a manufacturer show some scatter caused by manufacturing tolerances but are described by mean values and curves which represent that size.

The total consumption of electric energy by water pumps installed in applications within the scope of this document depends on the total number of installed pumps of each size and on its mean efficiency. The quality of a size in respect to its mean efficiency is quantitatively described by the Minimum Efficiency Index (MEI) which is defined and used in this document. To achieve a certain value of the Minimum Efficiency Index (MEI), a corresponding minimum value of the mean efficiency of a size is required.

This document defines – for each pump type and size within the scope of this document - the minimum required value of efficiency regarding a certain value of the Minimum Efficiency Index (MEI).

Normally, the qualification of a pump size for a certain MEI value done by the manufacturer will be based on tests and evaluations made on a sample of pumps of this size. Tests and evaluations carried out for the purpose of qualifying the corresponding size should fulfil certain requirements:

— From the tests on the sample pumps, it becomes possible to predict for the corresponding size the confidence intervals within which the true mean values of efficiencies which are relevant for the qualification are enclosed with a sufficiently high probability. Only in that way, the qualification of the size in respect to a required and/or indicated value of Minimum Efficiency Index (MEI) will ensure that the aspired effect of energy saving will be reached;

— This document provides manufacturers with a test procedure which confidently provides the MEI value which is representative of the pump size.

Caused by technical alignment procedures of the single pump components e.g. bearings or shaft seals the performance of the pump is gained after a certain running-in time.

Ways to prove the Minimum Efficiency Index (MEI) of a pump size

This document describes different ways how manufacturers can achieve the qualification of a pump size for a certain value of the Minimum Efficiency Index (MEI)

The MEI value shall be based on the mean value of the type series. Annex C describes methods to determine the mean value of MEIs and their confidence intervals.

A test to determine MEI-values on pumps of the size in question according to the requirements given in 6.2 to 6.4 of this document as well as evaluations as described in 6.5 of this document needs application of the methodology and procedure described in Clause 5 of this document.

Relevance of clauses of this document for qualification

Clause 5 describes nominal values of minimum required efficiency for a certain value of the Minimum Efficiency Index (MEI) and is generally relevant when applying this document.

Clause 6 specifies test procedures, test conditions and evaluations and has to be applied to determine mean values of a size by tests on sample pumps of a certain size.

Clause 7 describes the procedure to be applied by a manufacturer in order to determine particular threshold values of efficiency for a certain value of the Minimum Efficiency Index (MEI) of a size and to prove the justification of this MEI value by the fulfilment of criteria for the mean efficiency values.

1 Scope

This document specifies performance requirements (methods and procedures for testing and calculating) for determining the Minimum Efficiency Index (MEI) of rotodynamic glanded water pumps for pumping clean water, including where integrated in other products.

The pump types and sizes covered by this document are described in the Annex A. These pumps are designed and produced as duty pumps for pressures up to 16 bar for end suction pumps and up to 25 bar for multistage pumps, for all pumps designed for fluid temperatures between −10 °C and +120 °C. Also covered are 4” (10,16 cm) and 6” (15,24 cm) submersible multistage pumps designed for fluid temperatures between 0 °C and 90 °C.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

EN ISO 9906:2012, *Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3 (ISO 9906:2012)*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1 List of quantities with definitions[1)]

3.1.1
reynolds number

dimension less number that gives a measure of the ratio of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions; in this document, it is defined by the relation:

$$\mathrm{Re} = \frac{D_{\mathrm{imp}} \cdot u}{\nu}$$

where u is the peripheral velocity at the outer impeller diameter D_{imp}

3.1.2
(volume) rate of flow

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

Note 1 to entry: Losses or abstractions inherent to the pump, i.e.:

— discharge necessary for hydraulic balancing of axial thrust;

1) 3.1 gives specific definitions of terms - in deviation of EN ISO 9906:2012 - used in this document, together with any associated symbols which have been allocated and is based on ISO 80000.

— cooling of bearings of the pump itself;

— water seal to the packing;

Note 2 to entry: Leakage from the fittings, internal leakage, etc., is not to be reckoned in the rate of flow. On the contrary, all derived flows for other purposes, such as cooling of the motor bearings; cooling of a gear box (bearings, oil cooler), etc. are to be reckoned in the rate of flow.

Note 3 to entry: Whether and how these flows shall be taken into account depends on the location of their derivation and of the section of flow-measurement respectively.

3.1.3
motor power input
power (P_1) absorbed by the pump driver

3.1.4
pump efficiency

$$\eta = \frac{P_{\text{hyd}}}{P_2} = \frac{\textit{Pump power output}}{\textit{Pump power input}}$$

3.1.5
motor efficiency

$$\eta_{mot} = \frac{P_2}{P_1} = \frac{\textit{Pump power input}}{\textit{Motor power input}}$$

3.1.6
overall efficiency

$$\eta_{\text{tot}} = \frac{P_{\text{hyd}}}{P_1} = \frac{\textit{Pump power output}}{\textit{Motor power input}}$$

3.1.7
specific speed
dimensional number characterising the impeller type (radial, semi-axial, axial) of rotodynamic pumps

$$n_s = n_N \cdot \frac{\sqrt{Q_{\text{BEP}}}}{H_{\text{BEP}}^{0,75}}$$

Note 1 to entry: For multistage pumps, H_{BEP} is the head per stage which results from dividing the total pump head at the point of best efficiency by the number of stages i.

Note 2 to entry: The specific speed of an individual pump or the mean specific speed of a pump size is a (dimensional) value which characterizes the impeller shape (radial, semi-axial, axial) of the pump or the size. The numerical value of the specific speed is defined by a formula given in this Clause by using special units for the quantities contained in this formula. As described in Clause 5, the specific speed is one of the parameters, which the nominal values of minimum required efficiency depend on.

Note 3 to entry: Specific speed can be interpreted as the rotational speed of the pump with a flow of 1 m^3/s and the head of 1m and is described in [1/min], although this is not due to the balance of units.

3.1.8
minimum efficiency index (MEI)
value which determines the minimum required efficiency for the qualification criteria and, thereby, is a measure of the quality of a pump size in respect to efficiency

Note 1 to entry: Dimensionless scale unit for hydraulic pump efficiency at BEP, PL and OL.

Note 2 to entry: The MEI is the result of a statistical analysis of the performances of a large number of commercial pump sizes, and corresponds to the various “quartiles” of the statistical distribution.

EXAMPLE MEI = 0,40 corresponds to the efficiency performance level that 40 % of the pumps on the market do not meet [7].

3.2 General definitions

3.2.1
qualification
procedure where the manufacturer of the pump size proves, by appropriate methods, a given value of the MEI (e.g. the value on the nameplate)

Note 1 to entry: Generally, the qualification criteria refer to the mean values of the size which are valid for the full impeller diameter and which will be determined by tests and evaluations on pumps of the respective size. These mean efficiency values and their confidence intervals are compared to nominal values of minimum required efficiency. Also, these values depend on parameters (see Clause 5) the values of which partly result from the tests and are determined with some uncertainty or tolerance.

3.2.2
minimum required efficiency $\eta_{min,requ}$
value of efficiency that shall be reached in order to fulfil a particular MEI value

Note to entry: The value of minimum required efficiency depends on certain properties of the pump size (pump type, nominal speed of rotation, flow rate at best efficiency point and specific speed) and on the Minimum Efficiency Index (MEI). For one size, different minimum required efficiencies are relevant at best efficiency point, at specified part load and overload operating points, respectively.

3.2.3
particular threshold values of efficiency ($\eta_{threshold}$)
nominal values calculated from the minimum required efficiency respecting random sample scatter and measurement uncertainty

3.2.4
pump size
range of pumps characterized by certain dimensions and performance (e.g. nominal diameter of discharge flange and nominal impeller diameter for end-suction and multistage pumps, number of stages for multistage pumps, nominal outer casing diameter in the case of submersible multistage pumps) and given in catalogues by a manufacturer

Note to entry: In a Q-H-chart each pump size covers a certain range of Q- and H-values. Within this range each duty point can be served by a pump of the corresponding pump size through adapting its Q-H-curve by impeller trimming, i.e. by cutting down the outer impeller diameter to an appropriate value. The upper limit of the Q-H-range covered by one pump size is determined by the full diameter of the impeller corresponding to this size.

3.2.5
full impeller diameter of a pump size
impeller with the maximum diameter for which performance characteristics are given for a pump size in the catalogues of a water pump manufacturer

3.2.6
best efficiency point, BEP
operating point where the greatest value of pumps efficiency is obtained, at nominal speed of rotation

3.2.7
part load PL
particular operating point in the range of operating points with lower flow than best efficiency point, at nominal speed of rotation

3.2.8
overload OL
particular operating point in the range of operating points with higher flow than best efficiency point, at nominal speed of rotation

4 Symbols and abbreviations

Table 1 gives an alphabetical list of symbols used and Table 2 gives a list of subscripts. As far as possible, the quantities, definitions and symbols used in this document comply with those used in EN ISO 9906:2012. Quantities, definitions and symbols used in EN ISO 9906:2012, but not needed in this document are not contained in Clause 5 and Tables 1 and 2 while these tables contain some quantities, definitions and symbols which are not used in EN ISO 9906:2012.

In this document all formulae are given in coherent SI-units.

Table 1 — Alphabetical list of basic letters used as symbols

Symbol	Quantity	Unit
A	Area	m^2
C	Constant	pure number
D	Diameter	m
e	Measurement uncertainty, relative value	pure number
f	Frequency	s^{-1}, Hz
g	Acceleration due to gravity	m/s^2
H	Pump total head	m
k	Number of instrument readings or sample pumps	pure number
m	Mass	kg
M	Number of pumps of a sample	pure number
n	Speed of rotation	s^{-1}, min^{-1}
N	Number of instrument readings	pure number
n_S	Specific speed	min^{-1}
p	Pressure	Pa
p	Probability	pure number
P	Power	W

Symbol	Quantity	Unit
Q	(Volume) rate of flow	m^3/s
s	Standard deviation of a sample	according to special quantity
t	Tolerance factor, relative value	pure number
t	Time	s
t	Student's factor	pure number
T	Torque	Nm
u	Peripheral velocity	m/s
U	Mean velocity	m/s
U	Voltage	V
v	Local velocity	m/s
V	Volume	m^3
x	General quantity	according to special quantity
y	General quantity	according to special quantity
z	Height above reference plane	m
z	Number of produced pumps	pure number
η	Efficiency	pure number
θ	Temperature	°C
ν	Kinematic viscosity	m^2/s
ρ	Density	kg/m^3
ω	Angular velocity	rad/s
σ	Standard deviation of normal distribution	according to special quantity

NOTE For a list of concise designations (short-term description) of pump types in scope, see Annex B.

Table 2 — List of letters and figures used as subscripts

Subscript	Meaning
1	electrical
2	mechanical
abs	absolute
amb	ambient
annual	per year
curve	on fitting curve
BEP	at best efficiency point
mot	motor
D	datum
exp	experimentally determined

Subscript	Meaning
G	guaranteed
H	pump total head
I	numbering index
J	numbering index
imp	impeller
man	manufacturing
max	maximum permissible
mean	mean value of pump series
min,requ	minimum required
N	nominal
OL	overload
Pd	pre-defined
P	power
PL	part load
Q	(volume) flow rate
R	random
S	specific, systematic
sync	synchronous
tot	total, overall
true	true value
T	torque
T	translated
v	vapour
x	of quantity x
y %	for probability of y %
η	Efficiency
hyd	hydraulic

5 Minimum Required Efficiencies and Minimum Efficiency Index

5.1 The concept of "house of efficiency"

To achieve the goal of energy saving by replacing less energy efficient pumps with pumps which are qualified in respect to fulfilling criteria of minimum required efficiency, two important aspects shall be taken into account:

1) The required minimum values of $\eta_{\mathrm{min,req}}$ shall be fulfilled by the mean values of the qualified pump sizes which are produced and sold in large numbers. Therefore, these mean values and their confidence intervals shall be determined by appropriate methods and then be compared to minimum required values

(Formula 4) which are based on general physical interrelations (see Annex B) as well as on a statistical evaluation of existing pumps of ”state of the art” design and manufacturing quality.

2) Not only the value of η_{BEP} is relevant for energy consumption and saving by pumps, but also the efficiency in the part load and overload ranges of operation. This is caused by two reasons:

The product program of pump manufacturers for a certain pump type is – from economic reasons – subdivided into a limited number of different pump sizes which each cover a certain range of flow rate Q and pump head H. This leads to the effect that most unlikely for any Q-H duty point (i.e. the operating point specified by the pump user which normally is the most probable point of operation) for a pump application, a pump size will exist for which its best efficiency point is identical to the required duty point. The selection of the “best choice” size for a given application will most often cause the duty point to be a slight “off-design”, i.e. part load or overload, point of the selected size. (For more information to aspects of pump selection, see Annex B)

Even if the best efficiency point of a pump size fits exactly to a required duty point, the pump will normally be operated in a range of operation and not only at its duty point. This can result from changes or variations of the hydraulic resistance of the circuit (caused either by varying demand of system flow rate or by long time effects as, e.g. internal incrustation of pipes) or, in the case of parallel operation of pumps, from variable operation conditions when different numbers of pumps are running.

Therefore, the qualification of a pump size in respect to minimum required efficiency is based on the so-called concept “house of efficiency” which includes two criteria A and B.

Criterion A is the minimum efficiency requirement at the best efficiency point (BEP) of the pump size:

$$\text{A. } \left(\eta_{\text{BEP}}\right)_{\text{mean}} \geq \left(\eta_{\text{BEP}}\right)_{\text{min, requ}} \tag{1}$$

Criterion B is the minimum efficiency requirement at specified part load (PL) and overload (OL) operating points of the pump size:

$$\text{B. } \left(\eta_{\text{PL}}\right)_{\text{mean}} \geq \left(\eta_{\text{PL}}\right)_{\text{min,requ}} \tag{2}$$

$$\left(\eta_{\text{OL}}\right)_{\text{mean}} \geq \left(\eta_{\text{OL}}\right)_{\text{min,requ}} \tag{3}$$

In this document, the operating points which shall be representative for the efficiency in the part load and overload range are fixed at Q_{PL} = 0,75 Q_{BEP} and Q_{OL} = 1,1 Q_{BEP}.

All efficiency values in the criteria given above are mean values of the pump size and are to be taken for pumps of this size with full impeller diameter.

As a result, the mean efficiency curve of the size has to show a high maximum and a broad width at high level to fulfil the criteria for qualification.

In Figure 1, the representation of the two criteria is shown in a Q-η diagram. To be qualified, the mean efficiency curve of the size with its maximum at the best efficiency point shall not penetrate into the “roof” of the “house of efficiency”.