SLOVENSKI STANDARD
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Črpalke - Metode za kvalifikacijo in verifikacijo indeksa energijske učinkovitosti centrifugalnih črpalk - 2. del: Preskušanje in računanje indeksa energijske učinkovitosti (IEE) enodelnih črpalk

Pumps - Methods of qualification and verification of the Energy Efficiency Index for rotodynamic pumps units - Part 2: Testing and calculation of energy Efficiency Index (EEI) of single pump units

Pumpen - Methoden zur Qualifikation und Verifikation des Energieeffizienzindexes für Kreiselpumpen - Teil 2: Prüfung und Berechnung des Energieeffizienzindexes (EEI) einzelner Pumpenaggregate

Pompes - Méthodes de qualification et de vérification de l'indice de rendement énergétique des groupes motopompes rotodynamiques - Partie 2 : Essais et calcul de l'indice de rendement énergétique (EEI) des groupes motopompes simples

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This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 197.

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European foreword

This document (prEN 17038-2:2016) has been prepared by Technical Committee CEN/TC 197 “Pumps”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

Introduction

This part of the European standard is the second part of a series of standards describing a methodology to evaluate energy efficiency performance of single pump units, comprising the pump, the motor with or without frequency converter, based on a non-dimensional numerical value called Energy Efficiency Index (EEI). An EEI allows the comparison of different pump sizes and types with one common indicator. Physical influences such as pump size, specific speed, pump unit part-load operation, motor-efficiency characteristic and frequency converter influence are implemented into this metric.

Specific requirements for testing and a calculation method for an EEI, the so called semi-analytical model of a complete single pump unit, specific flow-time profiles and reference control curves are given in this part of the standard.

EEI is an index to rate pump units according to their energy efficiency but does not replace the need to do a life-time cost analysis regarding energy consumption over the life time of the pump unit.

1 Scope

This European standard specifies methods and procedures for testing, calculating and determining the Energy Efficiency Index (EEI) of rotodynamic glanded single pump units for pumping clean water, including where integrated in other products.

The pump types and sizes covered by this standard are described in the normative Annex A.

2 Normative references

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

EN ISO 17769-1, *Liquid pumps and installation — General terms, definitions, quantities, letter symbols and units — Part 1: Liquid pumps (ISO 17769-1)*

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

EN 16480, *Pumps — Minimum required efficiency of rotodynamic water pumps*

FprEN 17038-1, *Pumps — Methods of qualification and verification of the energy efficiency Index forRotodynamic pumps units — Part 1: General requirements and procedures for testing and calculation of energy efficiency index (EEI)*

EN 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

EN 60034-30-1, *Rotating electrical machines — Part 30-1: Efficiency classes of line operated AC motors (IE-code) (IEC 60034-30-1)*

EN 60034-2-1, *Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles) (IEC 60034-2-1)*

EN 60034-2-2, *Rotating electrical machines — Part 2-2: Specific methods for determining separate losses of large machines from tests — Supplement to IEC 60034-2-1*

IEC TS 60034-2-3, *Rotating electrical machines — Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC induction motors*

EN 60038, *CENELEC standard voltages*

FprEN 61800-9-1, *Adjustable speed electrical power drive systems — Part 9-1: Energy efficiency of power drive systems, motor starters, power electronics and their driven applications — General requirements for setting energy efficiency standards for power driven equipment using the Extended Product Approach (EPA) and semi analytic model (SAM)*

FprEN 61800-9-2, *Adjustable speed electrical power drive systems — Part 9-2: Ecodesign for power drive systems, motor starters, power electronics & their driven applications — Energy efficiency indicators for power drive systems and motor starters*

3 Terms and definitions

For the purpose of this document the terms and definitions given in EN ISO 17769-1 and the following apply.

3.1
unit efficiency
hydraulic power output divided by electric power input also called “wire to water efficiency”

$$\eta_{unit} = P_{hyd} / P_1$$

3.2
constant flow operation
slight variations of the flow rate around the nominal value

NOTE Caused by secondary influences from the process as, for example, due to the (moderately) varying level of liquid in reservoirs etc. The variation of flow rate occurs typically within the range which is covered by the definition and determination of the Minimum Efficiency Index (MEI) of the pump, see EN 16480, and which is from 0,75 · $Q_{100\,\%}$ to 1,1 · $Q_{100\,\%}$.

3.3
variable flow
widely varying flow rate

Note 1 to entry: Typically, at considerable fractions of the total operating time, the actual demand for pump flow rate Q and pump head H is much lower than the values at the operating point of maximum flow rate which is demanded by the application.

3.4
Hydraulic Power
conventional expression of the arithmetic product of the flow *Q* and the head *H* and a constant

Note 1 to entry:

$$P_{hyd} = \rho_W \cdot g \cdot \left(Q / 3600 \right) \cdot H$$

where

P_{hyd}	is the hydraulic power [W];
Q	is the flow [m^3/h];
H	is the total Head [m];
ρ_W	is the density of the test water 1 000 kg/m^3;
g	is the gravitational constant *of* 9,81 m/s^2.

3.5
maximum hydraulic power
absolute maximum $P_{hyd,max}$ of hydraulic power of a pump unit

3.6
set of parameters which cause the pump unit to generate the curve of maximum hydraulic power

Note 1 to entry: The pump unit needs to be capable and designed to run in maximum operation continuously.

3.7
pump unit best efficiency point, ($Q_{BEP,unit}$ / $H_{BEP,unit}$)
Flow-Head-Point where the pump unit runs at its best unit efficiency point and at maximum operation

3.8
reference flow rate, $Q_{100\%}$
flow per time unit [m³/s] at the Best Efficiency Point (BEP) of the unit

3.9
reference head, $H_{100\%}$
total differential head [m] at the Best Efficiency Point (BEP) of the unit

3.10
flow-time profile
pattern of percentiles of time where the pump unit runs at a given flow rate

3.11
Complete Drive Module (CDM)
electronic power converter connected between the electric supply and a motor as well as extensions such as protection devices, transformers and auxiliaries (according to EN 61800-2)

3.12
Power Drive System (PDS)
combination of CDM and motor

4 Reference flow-time profiles and reference pressure control curves

4.1 General

When putting single pump units into service an appropriate EEI value shall be made available. The EEI shall be for variable flow (EEI_V) and/or constant flow (EEI_C) according to the demand of the application in which the pump unit is put into service or for which the pump unit is specified when placed on the market. For the determination of the EEI_V or EEI_C the respective reference flow-time profiles and the reference pressure control curves given in Table 1 have to be applied.

Table 1 — Reference load flow profiles and reference pressure control curves for single pump units

Mode			Reference flow-time profile	Reference pressure control curve	Applicable Q/H test points	EEI applicable
#	Demand of application	Type of Pump Unit				
M1	constant flow	fixed speed	constant flow (Table 2)	Q/H curve of the pump unit	On Q/H curve of the pump unit	EEI_C
M2	variable flow	fixed speed	variable flow (Table 3)	Formula (1)	On Q/H curve of the pump unit	EEI_V
M3	constant flow	variable speed	constant flow (Table 2)	Q/H curve of the pump unit	On Q/H curve of the pump unit (measured at fixed speed)	EEI_C
M4	variable flow	variable speed	variable flow (Table 3)	Formula (1)	Q/H points on curve defined by Formula (1)	EEI_V
M5	constant flow, varying head	variable speed	variable flow (Table 3)	Formula (1)	Q/H points on curve defined by Formula (1)	EEI_V

In case of a bare shaft pump alone to be *placed on the market* the EEI shall be determined with a reference motor (refer to Class "IE3" in EN 60034-30-1) in mode M1 depending on the nominal speed of the bare shaft pump (either 2-pole type for the pump nominal speed $n_{N,PU}$ = 2 900 1/min or is of the 4-pole type for the pump nominal speed $n_{N,PU}$ = 1 450 1/min). The reference motor shall have a nominal power output which exactly equals the shaft power of the pump at its nominal operating conditions.

4.2 Reference flow-time profiles

The reference flow time profile for constant flow operation is shown in Table 2.

Table 2— Reference flow-time profile for constant flow operation

Flow Q in % of $Q_{100\%}$	75	100	110
Time Δt in % of total operating time	25	50	25

The reference flow time profile for variable flow operation is shown in Table 3.

Table 3 — Reference flow-time profile for variable flow operation

Flow Q in % of $Q_{100\%}$	25	50	75	100
Time Δt in % of total operating time	44	35	15	6

4.3 Reference pressure control curves

In the case of the variable flow demand, the reference control curve is defined by Formula (1).

$$H_i / H_{100\%} = 100 \cdot \left[0{,}5 + 0{,}5 \cdot \left(Q / Q_{100\%} \right) \right] \quad [\%] \tag{1}$$

The values $H_i/H_{100\%}$ at the corresponding values of $Q_i/Q_{100\%}$ of the reference flow-time profile are given according to Formula (1).

The reference pressure control curve defined by Formula (1) with the corresponding hydraulic load points given in Table 2 and 3 in numerical form additionally are plotted graphically in Clause 5, Figure 2.

In the case of the constant flow mode, the reference control curve is the Q/H curve of the actual pump unit applied to define $Q_{100\%}$, $H_{100\%}$ (see also Clause 5, Figure 1).

In the case of the constant flow and varying head demand (mode M5), the reference control curve is defined by Formula (1).

5 Determination of average electric power input $P_{1,avg}$ by test

5.1 General

5.1.1 Test requirements

This clause specifies performance tests and evaluations for pump units which are carried out

— either by a company which places the pump units on the market and/or puts them into service,

— or by an independent institution in the frame of the verification procedure described in FprEN 17038-1:2016, Clause 6.

Such tests shall provide the necessary information on the actual performance values of test pump units needed for the calculation of the EEI-value according to its definition given in FprEN 17038-1:2016, Clause 4.

All provisions for the test concerning the pump shall be in accordance with EN ISO 9906, class 2. The exception for input power of 10 kW and below (as allowed for the application of EN ISO 9906 on acceptance tests) shall not be valid.

All provisions for the test concerning an electric motor if it is part of the pump unit and is fed directly from an electric grid shall be in accordance with EN 60034-2-1.

All provisions for the test concerning a Power Drive System if is part of the pump unit shall be in accordance with FprEN 61800-9-2.

5.1.2 Test conditions

Tests shall be carried out with clean cold water. The performance of a pump varies substantially with the nature of the liquid being pumped. It is not possible to give general rules whereby performance results measured with clean cold water can be converted to predict performance with water having other properties (temperature, content of solids or gas) or other liquids.

The duration of the test shall be sufficient to obtain repeatable results; especially run-in and warming-up effects of the electric and electronic components of the unit shall be considered.

NOTE 1 Run-in effects may take up to one day operating time.

All measurements shall be made under steady state conditions (see EN ISO 9906, EN 60034-2-1, EN 60034-2-2 and IEC TS 60034-2-3 and FprEN 61800-9-2).

NOTE 2 prEN 61800–9-2 allows warming up the PDS for measuring the nominal point. All other points can be measured quickly after measuring maximum load without waiting for the steady-state.

The tests should be conducted under conditions where cavitation does not affect the performance of the pump.

NOTE 3 If cavitation exists to a remarkable extent in the test pump during the test, not only the pump head but also the pump efficiency and the power input can deteriorate which leads to an underestimation of the energy efficiency of the pump unit.

For Case 1 in 5.2.1 (motor fed by an electric supply with constant frequency) the electric power supply of the test installation shall fulfil the requirements as specified in EN 60034-1. This requires that

— the voltage shall be in accordance with 7.2 of EN 60038 and EN 60034-1,

— the frequency shall be within ± 0,3 % of the rated frequency during measurements.

For Case 2 in 5.2.1 (PDS, i.e. motor combined with and fed by a CDM) the following requirements have to be fulfilled in accordance to FprEN 61800-9-2:

— When testing a PDS under the load of the pump, slow fluctuations in the measured quantities may be unavoidable. Therefore for each load point several measurements over a period of time (at least several slip cycles, typically 1 min to 3 min) shall be sampled and the average of these values shall be used for the evaluation.

— Pump units equipped with a PDS shall be measured with a screened cable between CDM and motor of a maximum length of 10 m.

— The measurements shall be done when the PDS is thermally stable (the temperature gradient shall be maximal 2 K per hour).

5.1.3 Measuring instrumentation

For the test procedures described in 5.1.1 measuring instrumentation is needed for the determination of:

— the flow rate Q;

— the pump head H;

— the electric power input P_1.

Since instrument accuracy is generally expressed as a percentage of full scale, the range of the instruments chosen shall be as small as practical.

For analogue instruments the observed values should be in the upper third of the instrument range.

The measuring equipment needed to determine the flow rate Q and the pump head H shall be selected in accordance with EN ISO 9906. Detailed information is given in EN ISO 9906:2012, A.1.

For the determination of the electric power input P_1 in case 1 in 5.2.1 (motor directly fed by the electric grid) the electric input power P_1 is determined based on input voltages U and input currents. All requirements concerning the instrumentation for the measurements of P_1 shall be fulfilled according to EN 60034-2-1.

For the determination of the electric power input P_1 in case 2 in 5.2.1 (motor combined with and fed by a CDM), the electric input power P_1 shall be measured according to “input-output measurement method” in FprEN 61800-9-2. All requirements concerning the instrumentation for the measurement of P_1 shall be fulfilled according to FprEN 61800-9-2.

5.2 Calculation of load points

5.2.1 General

As explained in FprEN 17038-1:2016, Clause 4, the value of the Energy Efficiency Index (EEI-value) is based on the electric power input P1 of the pump unit when the pump is operated at the hydraulic load points specified in FprEN 17038-1:2016, 4.2. The test aims at determining the electric power input P1 of the pump unit at the N values of pump flow rate *Q* defined by the reference flow-time profile.

For the test procedure, different cases have to be distinguished:

1) Case 1 Fixed speed operation: the electric motor of the pump unit is fed by a constant stator frequency, either grid frequency or a different frequency fed from a CDM and therefore, can only be operated at (nearly) constant rotational speed *n.* In this case only the pump flow rate *Q* can be controlled during the test. The flow rate *Q* shall be adjusted to the various values of the reference flow-time profile while the head *H* generated by the pump is given by the *Q*-*H*-curve of the pump at constant motor stator frequency. Besides the electric power input P_1, the actual values of the pump flow rate *Q* and head *H* have to be measured and documented.

2) Case 2 Variable speed operation: the pump unit has to be operated at variable rotational speed along a pressure control curve. In the test, the flow rate *Q* shall be adjusted to the various values of the reference flow-time profile. The pump head *H* shall be adjusted to the values according to the reference pressure control curve.

For each load point, the flow rate *Q* which is adjusted and measured shall not deviate from the values according to the reference flow-time profile by more than ± 2 % (or ± 0,1 m³/h, whichever is the largest absolute value).

The measured value $H_{measured}$ shall not deviate more than ± 5 % (or ± 0,2 m Head, whichever is the largest absolute value) from the values H_i according to the reference pressure control curve.

For pump units where the pump is of the multistage type and which are offered and sold with different numbers of stages, the tests on test pump units which should be representative (in respect to the Energy Efficiency Index) for the type series shall be carried out on pump versions with the actual number of stages for vertical and horizontal multistage pumps.

Measurement shall be done on actual pump impeller diameter.

5.2.2 Determination of $Q_{100\,\%}$ and $H_{100\,\%}$

As a first step of the test procedure $Q_{100\%}$ shall be determined. For this purpose the pump unit shall be set to maximum operation.

Maximum operation for a pump unit running at fixed speed is achieved by feeding the motor with a constant stator frequency, this may be the grid frequency or a different frequency fed from a CDM to run the pump unit at maximum hydraulic power.

Maximum operation for a pump unit running with variable speed is achieved by allowing the controller to adjust the speed of the actual pump unit to values which derive a curve with maximum hydraulic power.

NOTE In case where the H-Q-curve of the pump is cut off to avoid overload of the motor the $Q_{100\,\%}$ point could be located at the maximum flow (Q_{max}) of the pump unit (right end of curve) then $Q_{100\,\%} = Q_{max}$.

The best efficiency point ($Q_{100\%}$ /$H_{100\%}$) is then located on this pump unit curve.

The point ($Q_{100\%}$ /$H_{100\%}$) defines the flow rate corresponding to the reference flow time profiles and the reference pressure control curve.

Target values of the flow rate Q have to be determined. In the case of variable flow, $H_{100\%}$ is also required so that the head points along the reference pressure control curve can be found. In case of fixed flow the head values are determined by the pump unit head-flow-curve.

For the purpose of determining the needed H-Q-points of the reference flow time profile and the reference pressure control curve, values of flow rate Q, pump head H and electric power input P1 have to be measured at maximum operation for a sufficient number of operating points around the expected value of $Q_{BEP,unit}$.

For the choice of these operating points, the value of $Q_{BEP,PU}$ at $n = n_{N,PU}$ given in the documentation of the pump manufacturer can be taken as a preliminary estimation for the expected value of $Q_{100\%}$. It is important to take measurement data in a sufficiently large range of Q below and above the expected value of $Q_{100\%}$ (Recommended $0,7 \cdot Q_{100\%} < Q = 1,3 \cdot Q_{100\%}$).

If the value of $Q_{100\%}$ calculated on the basis of the test points shows that less than 3 of the test points were at values of Q greater than this calculated value, additional test points shall be added to generate at least 3 test points at values of Q greater than $Q_{100\%}$.

The value of $H_{100\%}$ can be calculated by inserting $Q = Q_{100\%}$ into Formula (7).

5.2.3 Determination of part load and over load points and reference control curve

The reference flow points of the flow rate Q_i shall be calculated by the following formula:

$$Q_i = \left(\frac{Q}{100}\right)_i \cdot Q_{100\%} \tag{2}$$

Where the values Q corresponding to the *N* load points of the reference load flow profile are taken from Table 2 or Table 3.

To determine the $Q_{110\%}$-point for the case where the H-Q-curve of the pump is cut off to avoid overload of the motor and the $Q_{100\%}$ point could be located at the maximum flow (Q_{max}) of the pump unit (right end of curve) the motor may be overloaded for a short time in the test and the ($Q_{110\%}$, $H_{110\%}$) may be measured or the Formulae (7) and (8) may be used.

In the case of variable flow operation the reference head points H_i shall be calculated by the following formulae:

$$H_i = \left(\frac{H}{100}\right)_i \cdot H_{100\%} \tag{3}$$

Where the values H corresponding to the *N* load points on the reference pressure control curve taken from Table 5.

In the case of constant flow operation the head points *H* are defined by the pump curve applied when defining $Q_{100\%}$, $H_{100\%}$.

For variable speed pump units on fixed flow, the test is at fixed speed with head points along the fixed nominal speed Q-H-curve. For fixed speed on variable flow the head cannot be adjusted to the reference pressure control curve and follows the pump unit Q-H-curve.