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Subpart Y - Pumps

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Appendix A to Subpart Y of Part 431 - Uniform Test Method for the Measurement of Energy Consumption of Pumps

Note: Starting on July 25, 2016, any representations made with respect to the energy use or efficiency of pumps subject to testing pursuant to 10 CFR 431.464(a) must be made in accordance with the results of testing pursuant to this appendix.

I. Test Procedure for Pumps

A. ***General.*** To determine the constant load pump energy index (PEI_{CL}) for bare pumps and pumps sold with electric motors or the variable load pump energy index (PEI_{VL}) for pumps sold with electric motors and continuous or non-continuous controls, perform testing in accordance with HI 40.6-2014, except section 40.6.5.3, "Test report;" section A.7, "Testing at temperatures exceeding 30 °C (86 °F);" and appendix B, "Reporting of test results;" (incorporated by reference, see § 431.463) with the modifications and additions as noted throughout the provisions below. Where HI 40.6-2014 refers to "pump," the term refers to the "bare pump," as defined in § 431.462. Also, for the purposes of applying this appendix, the term "volume per unit time," as defined in section 40.6.2, "Terms and definitions," of HI 40.6-2014 shall be deemed to be synonymous with the term "flow rate" used throughout that standard and this appendix. In addition, the specifications of section 40.6.4.1 of HI 40.6-2014 do not apply to ST pumps and the performance of ST bare pumps considers the bowl performance only.

A. 1 Scope. Section II of this appendix is applicable to all pumps and describes how to calculate the pump energy index (section II.A) based on the pump energy rating for the minimally compliant reference pump (PER_{STD}; section II.B) and the constant load pump energy rating (PER_{CL}) or variable load pump energy rating (PER_{VL}) determined in accordance with one of sections III through VII of this appendix, based on the configuration in which the pump is distributed in commerce and the applicable testing method specified in sections III through VII and as described in Table 1 of this appendix.

Table 1 - Applicability of Calculation-Based and Testing-Based Test Procedure Options Based on Pump Configuration

Pump configuration	Pump sub-configuration	Applicable test methods
Bare Pump	Bare Pump OR Pump + Single-Phase Induction Motor OR Pump + Driver Other Than Electric Motor	Section III: Test Procedure for Bare Pumps.
Pump + Motor *	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards ** OR Pump + Submersible Motor	Section IV: Testing-Based Approach for Pumps Sold with Motors OR Section V: Calculation-Based Approach for Pumps Sold with Motors.
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors) ** ***	Section IV: Testing-Based Approach for Pumps Sold with Motors.
Pump + Motor + Continuous Controls OR Pump + Motor + Non-Continuous Controls	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards** + Continuous Control OR Pump + Submersible Motor + Continuous Control	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls OR Section VII: Calculation-Based Approach for Pumps Sold with Motors Controls.
	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards** + Non-Continuous Control OR Pump + Submersible Motor + Non-Continuous Control	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls.
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors) ** *** + Continuous or Non-Continuous Controls	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls.

* Also applies if unit is sold with controls other than continuous or non-continuous controls (*e.g.,* ON/OFF switches).

** All references to “Motors Covered by DOE's Electric Motor Energy Conservation Standards” refer to those listed at § 431.25(g) of this chapter.

*** Includes pumps sold with single-phase induction motors.

A. 2 Section III of this appendix addresses the test procedure applicable to bare pumps. This test procedure also applies to pumps sold with drivers other than motors and pumps sold with single-phase induction motors.

A. 3 Section IV of this appendix addresses the testing-based approach for pumps sold with motors, which is applicable to all pumps sold with electric motors, including single-phase induction motors. This test procedure also applies to pumps sold with controls other than continuous or non-continuous controls (*e.g.,* on/off switches).

A. 4 Section V of this appendix addresses the calculation-based approach for pumps sold with motors, which applies to:

(1) Pumps sold with polyphase electric motors regulated by DOE's energy conservation standards for electric motors at § 431.25(g), and

(2) Pumps sold with submersible motors.

A. 5 Section VI of this appendix addresses the testing-based approach for pumps sold with motors and controls, which is applicable to all pumps sold with electric motors (including single-phase induction motors) and continuous or non-continuous controls.

A. 6 Section VII of this appendix discusses the calculation-based approach for pumps sold with motors and controls, which applies to:

(1) Pumps sold with polyphase electric motors regulated by DOE's energy conservation standards for electric motors at § 431.25(g) and continuous controls and

(2) Pumps sold with submersible motors and continuous controls.

B. ***Measurement Equipment.*** For the purposes of measuring pump power input, driver power input to the motor or controls, and pump power output, the equipment specified in HI 40.6-2014 Appendix C (incorporated by reference, see § 431.463) necessary to measure head, speed of rotation, flow rate, temperature, torque, and electrical power must be used and must comply with the stated accuracy requirements in HI 40.6-2014 Table 40.6.3.2.3 except as noted in sections III.B, IV.B, V.B, VI.B, and VII.B of this appendix. When more than one instrument is used to measure a given parameter, the combined accuracy, calculated as the root sum of squares of individual instrument accuracies, must meet the specified accuracy requirements.

C. ***Test Conditions.*** Conduct testing at full impeller diameter in accordance with the test conditions, stabilization requirements, and specifications of HI 40.6-2014 (incorporated by reference, see § 431.463) section 40.6.3, "Pump efficiency testing;" section 40.6.4, "Considerations when determining the efficiency of a pump;" section 40.6.5.4 (including appendix A), "Test arrangements;" and section 40.6.5.5, "Test conditions.". For ST pumps, head measurements must be based on the bowl assembly total head as described in section A.5 of 40.6-2014 and the pump power input or driver power input, as applicable, must be based on the measured input power to the driver or bare pump, respectively; section 40.6.4.1, "vertically suspended pumps," does not apply to ST pumps.

C. 1 Nominal Speed of Rotation. Determine the nominal speed of rotation based on the range of speeds of rotation at which the pump is designed to operate, in accordance with sections I.C.1.1, I.C.1.2, I.C.1.3, I.C.1.4, or I.C.1.5 of this appendix, as applicable. When determining the range of speeds at which the pump is designed to operate, DOE will refer to published data, marketing literature, and other publicly-available information about the pump model and motor, as applicable.

C. 1.1 For pumps sold without motors, select the nominal speed of rotation based on the speed for which the pump is designed. For bare pumps designed for speeds of rotation including 2,880 to 4,320 revolutions per minute (rpm), the nominal speed of rotation shall be 3,600 rpm. For bare pumps designed for speeds of rotation including 1,440 to 2,160 rpm, the nominal speed of rotation shall be 1,800 rpm.

C. 1.2 For pumps sold with 4-pole induction motors, the nominal speed of rotation shall be 1,800 rpm.

C. 1.3 For pumps sold with 2-pole induction motors, the nominal speed of rotation shall be 3,600 rpm.

C. 1.4 For pumps sold with non-induction motors where the operating range of the pump and motor includes speeds of rotation between 2,880 and 4,320 rpm, the nominal speed of rotation shall be 3,600 rpm.

C. 1.5 For pumps sold with non-induction motors where the operating range of the pump and motor includes speeds of rotation between 1,440 and 2,160 rpm, the nominal speed of rotation shall be 1,800 rpm.

C. 2 Multi-stage Pumps. For RSV and ST pumps, perform testing on the pump with three stages for RSV pumps and nine stages for ST pumps. If the basic model of pump being tested is only available with fewer than the required number of stages, test the pump with the maximum number of stages with which the basic model is distributed in commerce in the United States. If the basic model of pump being tested is only available with greater than the required number of stages, test the pump with the lowest number of stages with which the basic model is distributed in commerce in the United States. If the basic model of pump being tested is available with both fewer and greater than the required number of stages, but not the required number of stages, test the pump with the number of stages closest to the required number of stages. If both the next lower and next higher number of stages are equivalently close to the required number of stages, test the pump with the next higher number of stages.

C. 3 Twin Head Pumps. For twin head pumps, perform testing on an equivalent single impeller IL pump, constructed by incorporating one of the driver and impeller assemblies of the twin head pump being rated into an adequate, IL style, single impeller volute and casing. An adequate, IL style, single impeller volute and casing means a volute and casing for which any physical and functional characteristics that affect energy consumption and energy efficiency are the same to their corresponding characteristics for a single impeller in the twin head pump volute and casing.

D. Data Collection and Analysis

D. 1 Damping Devices. Use of damping devices, as described in section 40.6.3.2.2 of HI 40.6–2014 (incorporated by reference, see § 431.463), are only permitted to integrate up to the data collection interval used during testing.

D. 2 Stabilization. Record data at any tested load point only under stabilized conditions, as defined in HI 40.6-2014 section 40.6.5.5.1 (incorporated by reference, see § 431.463), where a minimum of two measurements are used to determine stabilization.

D. 3 Calculations and Rounding. Normalize all measured data to the nominal speed of rotation of 3,600 or 1,800 rpm based on the nominal speed of rotation selected for the pump in section I.C.1 of this appendix, in accordance with the procedures specified in section 40.6.6.1.1 of HI 40.6-2014 (incorporated by reference, see § 431.463). Except for the "expected BEP flow rate," all terms and quantities refer to values determined in accordance with the procedures set forth in this appendix for

the rated pump. Perform all calculations using raw measured values without rounding. Round PER_{CL} and PER_{VL} to three significant digits, and round PEI_{CL}, and PEI_{VL} values, as applicable, to the hundredths place (*i.e.,* 0.01).

D. 4 Pumps with BEP at Run Out.

Test pumps for which the expected BEP corresponds to a volume rate of flow that is within 20 percent of the expected maximum flow rate at which the pump is designed to operate continuously or safely (*i.e.,* pumps with BEP at run-out) in accordance with the test procedure specified in this appendix, but with the following exceptions:

(1) Use the following seven flow points for determination of BEP in sections III.D, IV.D, V.D, VI.D, and VII.D of this appendix instead of those specified in those sections: 40, 50, 60, 70, 80, 90, and 100 percent of the expected.

(2) Use flow points of 60, 70, 80, 90, and 100 percent of the expected maximum flow rate of the pump to determine pump power input or driver power input at the specified load points in section III.E.1.1, IV.E.1, V.E.1.1, VI.E.1, and VII.E.1.1 of this appendix instead of those specified in those sections.

(3) To determine of PER_{CL} and PER_{STD}, use load points of 65, 90, and 100 percent of the BEP flow rate determined with the modified flow points specified in this section I.D.4 of this appendix instead of 75, 100, and 110 percent of BEP flow.

II. Calculation of the Pump Energy Index

A. Determine the PEI of each tested pump based on the configuration in which it is sold, as follows:

A.

1. For pumps rated as bare pumps or pumps sold with motors, determine the PEI_{CL} using the following equation:

$$PEI_{CL} = \frac{PER_{CL}}{PER_{STD}}$$

Where:

PEI_{CL} = the pump energy index for a constant load (hp),

PER_{CL} = the pump energy rating for a constant load (hp), determined in accordance with either section III (for bare pumps, pumps sold with single-phase induction motors, and pumps sold with drivers other than electric motors), section IV (for pumps sold with motors and rated using the testing-based approach), or section V (for pumps sold with motors and rated using the calculation-based approach) of this appendix, and

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp), as determined in accordance with section II.B of this appendix.

A. 2 For pumps rated as pumps sold with motors and continuous controls or non-continuous controls, determine the PEI_{VL} using the following equation:

$$PEI_{VL} = \frac{PER_{VL}}{PER_{STD}}$$

Where:

PEI_{VL} = the pump energy index for a variable load,

PER_{VL} = the pump energy rating for a variable load (hp) determined in accordance with section VI (for pumps sold with motors and continuous or non-continuous controls rated using the testing-based approach) or section VII of this appendix (for pumps sold with motors and continuous controls rated using the calculation-based approach), and

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp), as determined in accordance with section II.B of this appendix.

B. Determine the pump energy rating for the minimally compliant reference pump (PER_{STD}), according to the following equation:

$$PER_{STD} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i for the minimally compliant pump (hp), calculated in accordance with section II.B.1of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.

1. Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i (hp), calculated in accordance with section II.B.1.1 of this appendix,

L_i = the part load motor losses at load point i (hp), calculated in accordance with section II.B.1.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.1. Determine the pump power input to the minimally compliant pump at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i = \frac{P_{u,i}}{\alpha_i \times \left({}^{\eta_{pump,STD}}/_{100} \right)}$$

Where:

P_i = pump power input to the bare pump at load point i (hp),

α_i = 0.947 for 75 percent of the BEP flow rate, 1.000 for 100 percent of the BEP flow rate, and 0.985 for 110 percent of the BEP flow rate;

$P_{u,i}$ = the pump power output at load point i of the tested pump (hp), as determined in accordance with section II.B.1.1.2 of this appendix;

$\eta_{pump,STD}$ = the minimally compliant pump efficiency (%), calculated in accordance with section II.B.1.1.1 of this appendix; and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.1.1 Calculate the minimally compliant pump efficiency based on the following equation:

$\eta_{pump,STD} = -0.8500 \times \ln(Q_{100\%})^2 - 0.3800 \times \ln(Ns) \times \ln(Q_{100\%}) - 11.480 \times \ln(Ns)^2 + 17.800 \times \ln(Q_{100\%}) + 179.80 \times \ln(Ns) - (C + 555.60$

Where:

$\eta_{pump,STD}$ = minimally compliant pump efficiency (%),

$Q_{100\%}$ = the BEP flow rate of the tested pump at full impeller and nominal speed of rotation (gpm),

Ns = specific speed of the tested pump determined in accordance with section II.B.1.1.1.1 of this appendix, and

C = the appropriate C-value for the category and nominal speed of rotation of the tested pump, as listed at § 431.466.

B.1.1.1.1 Determine the specific speed of the rated pump using the following equation:

$$N_s = \frac{n_{sp} \times \sqrt{Q_{100\%}}}{(H_{100\%}/S)^{0.75}}$$

Where:

Ns = specific speed,

n_{sp} = the nominal speed of rotation (rpm),

$Q_{100\%}$ = the measured BEP flow rate of the tested pump at full impeller and nominal speed of rotation (gpm),

$H_{100\%}$ = pump total head at 100 percent of the BEP flow rate of the tested pump at full impeller and nominal speed of rotation (ft), and

S = the number of stages with which the pump is being rated.

B.1.1.2 Determine the pump power output at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate using the following equation:

$$P_{u,i} = \frac{Q_i \times H_i \times SG}{3956}$$

Where:

$P_{u,i}$ = the measured pump power output at load point i of the tested pump (hp),

Q_i = the measured flow rate at load point i of the tested pump (gpm),

H_i = pump total head at load point i of the tested pump (ft),

SG = the specific gravity of water at specified test conditions, which is equivalent to 1.00, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$L_i = L_{full} \times y_i$

Where:

L_i = part load motor losses at load point i (hp),

L_{full} = motor losses at full load (hp), as determined in accordance with section II.B.1.2.1 of this appendix,

y_i = part load loss factor at load point i determined in accordance with section II.B.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/_{100}\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the motor horsepower as determined in accordance with section II.B.1.2.1.1 of this appendix (hp), and

$\eta_{motor,full}$ = the default nominal full load motor efficiency as determined in accordance with section II.B.1.2.1.2 of this appendix (%).

B.1.2.1.1 Determine the motor horsepower as follows:

• For bare pumps other than ST pumps, the motor horsepower is determined as the horsepower rating listed in Table 2 of this appendix that is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump.

• For ST bare pumps, the motor horsepower is determined as the horsepower rating listed in Table 2 of this appendix that, is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump divided by a service factor of 1.15.

• For pumps sold with motors, pumps sold with motors and continuous controls, or pumps sold with motors and non-continuous controls, the motor horsepower is the rated horsepower of the motor with which the pump is being tested.

B. 1.2.1.2 Determine the default nominal full load motor efficiency as described in section II.B.1.2.1.2.1 of this appendix for pumps other than ST pumps or II.B.1.2.1.2.2 of this appendix for ST pumps.

B. 1.2.1.2.1. For pumps other than ST pumps, the default nominal full load motor efficiency is the minimum of the nominal full load motor efficiency standards (open or enclosed) from the table containing the current energy conservation standards for NEMA Design B motors at § 431.25, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section II.B.1.2.1.1 of this appendix.

B. 1.2.1.2.2. For ST pumps, the default nominal full load motor efficiency is the default nominal full load submersible motor efficiency listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section II.B.1.2.1.1 of this appendix.

B. 1.2.2 Determine the part load loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{MotorHP}\right)^3 + 1.2399 \times \left(\frac{P_i}{MotorHP}\right)^2 - 0.4301 \times \left(\frac{P_i}{MotorHP}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = pump power input to the bare pump at load point i (hp),

MotorHP = the motor horsepower (hp), as determined in accordance with section II.B.1.2.1.1 of this appendix,

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$, then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section II.B.1.2.2 to calculate the part load loss factor at each load point i.

III. Test Procedure for Bare Pumps

A. ***Scope.*** This section III applies only to:

(1) Bare pumps,

(2) Pumps sold with drivers other than electric motors, and

(3) Pumps sold with single-phase induction motors.

B. ***Measurement Equipment.*** The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section III, and in addition, when testing pumps using a calibrated motor:

(1) Electrical measurement equipment must be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) Any instruments used to measure a particular parameter specified in paragraph (1) must have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. ***Test Conditions.*** The requirements regarding test conditions presented in section I.C of this appendix apply to this section III. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(1) Maintain the voltage within ±5 percent of the rated value of the motor,

(2) Maintain the frequency within ±1 percent of the rated value of the motor,

(3) Maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and

(2) Maintain total harmonic distortion below 12 percent throughout the test.

D. ***Testing BEP for the Pump.*** Determine the best efficiency point (BEP) of the pump as follows:

D.

1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump and conduct the test at a minimum of the following seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6-2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see § 431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6-2014 (incorporated by reference, see § 431.463), where the pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6-2014, disregarding the calculations provided in section 40.6.6.2.

E. ***Calculating the Constant Load Pump Energy Rating.*** Determine the PER_{CL} of each tested pump using the following equation:

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i (hp), as determined in accordance with section III.E.1 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1 Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i (hp), as determined in section III.E.1.1 of this appendix,

L_i = the part load motor losses at load point i (hp), as determined in accordance with section III.E.1.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1.1 Determine the pump power input at 75, 100, 110, and 120 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the pump power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load points of 75, 100, 110, and 120 percent of the BEP flow rate.

E. 1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$L_i = L_{full} \times y_i$

Where:

L_i = motor losses at load point i (hp),

L_{full} = motor losses at full load (hp), as determined in accordance with section III.E.1.2.1 of this appendix,

y_i = loss factor at load point i as determined in accordance with section III.E.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/100\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp);

MotorHP = the motor horsepower (hp), as determined in accordance with section II.E.1.2.1.1 of this appendix, and

$\eta_{motor,full}$ = the default nominal full load motor efficiency (%), as determined in accordance with section III.E.1.2.1.2 of this appendix.

E. 1.2.1.1 Determine the motor horsepower as follows:

• For bare pumps other than ST pumps, determine the motor horsepower by selecting the horsepower rating listed in Table 2 of this appendix that is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump.

• For ST bare pumps, determine the motor horsepower by selecting the horsepower rating listed in Table 2 of this appendix that, is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump divided by a service factor of 1.15.

• For pumps sold with motors, pumps sold with motors and continuous controls, or pumps sold with motors and non-continuous controls, the motor horsepower is the rated horsepower of the motor with which the pump is being tested.

E. 1.2.1.2 Determine the default nominal full load motor efficiency as described in section III.E.1.2.1.2.1 of this appendix for pumps other than ST pumps or III.E.1.2.1.2.2. of this appendix for ST pumps.

E. 1.2.1.2.1. For pumps other than ST pumps, the default nominal full load motor efficiency is the minimum of the nominal full load motor efficiency standards (open or enclosed) from the table containing the current energy conservation standards for NEMA Design B motors at § 431.25, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section III.E.1.2.1.1 of this appendix.

E. 1.2.1.2.2. For ST pumps, the default nominal full load motor efficiency is the default nominal full load submersible motor efficiency listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section III.E.1.2.1.1 of this appendix;

E. 1.2.2 Determine the loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{MotorHP}\right)^3 + 1.2399 \times \left(\frac{P_i}{MotorHP}\right)^2 - 0.4301 \times \left(\frac{P_i}{MotorHP}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = pump power input to the bare pump at load point i (hp), as determined in accordance with section III.E.1.1 of this appendix,

MotorHP = as determined in accordance with section III.E.1.2.1 of this appendix (hp),

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$, then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section III.E.1.2.2 of this appendix to calculate the part load loss factor at each load point i.

IV. Testing-Based Approach for Pumps Sold With Motors

A. ***Scope.*** This section IV applies only to pumps sold with electric motors, including single-phase induction motors.

B. ***Measurement Equipment.*** The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section IV, and in addition, the electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. ***Test Conditions.*** The requirements regarding test conditions presented in section I.C of this appendix apply to this section IV. The following conditions also apply to the mains power supplied to the motor:

(1) Maintain the voltage within ±5 percent of the rated value of the motor,

(2) Maintain the frequency within ±1 percent of the rated value of the motor,

(3) Maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and

(4) Maintain total harmonic distortion below 12 percent throughout the test.

D. ***Testing BEP for the Pump.*** Determine the BEP of the pump as follows:

D. 1 Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6-2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see § 431.463).

D.

2. Determine the BEP flow rate as the flow rate at the operating point of maximum overall efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6-2014 (incorporated by reference, see § 431.463), where the overall efficiency is the ratio of the pump power output divided by the driver power input, as specified in Table 40.6.2.1 of HI 40.6-2014, disregarding the calculations provided in section 40.6.6.2.

E. ***Calculating the Constant Load Pump Energy Rating.*** Determine the PER_{CL} of each tested pump using the following equation:

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

P_i^{in} = measured driver power input to the motor at load point i (hp) for the tested pump as determined in accordance with section IV.E.1 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1 Determine the driver power input at 75, 100, and 110 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the driver power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the driver power input at the nominal speed of rotation for the load points of 75, 100, and 110 percent of the BEP flow rate.

V. Calculation-Based Approach for Pumps Sold With Motors

A. ***Scope.*** This section V can only be used in lieu of the test method in section IV of this appendix to calculate the index for pumps sold with motors listed in section V.A.1 or V.A.2 of this appendix.

A. 1 Pumps sold with motors subject to DOE's energy conservation standards for polyphase electric motors at § 431.25(g), and

A.

2. Pumps sold with submersible motors.

A.3. Pumps sold with motors not listed in sections V.A.1 or V.A.2 of this appendix cannot use this section V and must apply the test method in section IV of this appendix.

B. ***Measurement Equipment.*** The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section V, and in addition, when testing pumps using a calibrated motor electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. ***Test Conditions.*** The requirements regarding test conditions presented in section I.C of this appendix apply to this section V. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(1) Maintain the voltage within ±5 percent of the rated value of the motor,

(2) Maintain the frequency within ±1 percent of the rated value of the motor,

(3) Maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and

(4) Maintain total harmonic distortion below 12 percent throughout the test.

D. ***Testing BEP for the Bare Pump.*** Determine the best efficiency point (BEP) of the pump as follows:

D. 1 Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6-2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see § 431.463).

D.

2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6-2014 (incorporated by reference, see § 431.463), where pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6-2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. ***Calculating the Constant Load Pump Energy Rating.*** Determine the PER_{CL} of each tested pump using the following equation:

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i for the tested pump as determined in accordance with section V.E.1 of this appendix (hp), and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1 Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i, as determined in section V.E.1.1 of this appendix (hp),

L_i = the part load motor losses at load point i as determined in accordance with section V.E.1.2 of this appendix (hp), and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1.1 Determine the pump power input at 75, 100, 110, and 120 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the pump power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load points of 75, 100, 110, and 120 percent of the BEP flow rate.

E. 1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$L_i = L_{full} \times Y_i$

Where:

L_i = motor losses at load point i (hp),

L_{full} = motor losses at full load as determined in accordance with section V.E.1.2.1 of this appendix (hp),

y_i = part load loss factor at load point i as determined in accordance with section V.E.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E. 1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/_{100}\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp), and

$\eta_{motor,full}$ = the represented nominal full load motor efficiency (*i.e.,* nameplate/DOE-certified value) or default nominal full load submersible motor efficiency as determined in accordance with section V.E.1.2.1.1 of this appendix (%).

E. 1.2.1.1 For pumps sold with motors other than submersible motors, determine the represented nominal full load motor efficiency as described in section V.E.1.2.1.1.1 of this appendix. For pumps sold with submersible motors determine the default nominal full load submersible motor efficiency as described in section V.E.1.2.1.1.2 of this appendix.

E. 1.2.1.1.1. For pumps sold with motors other than submersible motors, the represented nominal full load motor efficiency is that of the motor with which the given pump model is being tested, as determined in accordance with the DOE test procedure for electric motors at § 431.16 and applicable representation procedures in parts 429 and 430.

E. 1.2.1.1.2. For pumps sold with submersible motors, the default nominal full load submersible motor efficiency is that listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower of the pump being tested.

E. 1.2.2 Determine the loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{MotorHP}\right)^3 + 1.2399 \times \left(\frac{P_i}{MotorHP}\right)^2 - 0.4301 \times \left(\frac{P_i}{MotorHP}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = the pump power input to the bare pump at load point i as determined in accordance with section V.E.1.1 of this appendix (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp),

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$ then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section V.E.1.2.2 of this appendix to calculate the part load loss factor at each load point i.

in the equation in this section V.E.1.2.2. of this appendix to calculate the part load loss factor at each load point

VI. Testing-Based Approach for Pumps Sold with Motors and Controls

A. ***Scope.*** This section VI applies only to pumps sold with electric motors, including single-phase induction motors, and continuous or non-continuous controls. For the purposes of this section VI, all references to "driver input power" in this section VI or HI 40.6-2014 (incorporated by reference, see § 431.463) refer to the input power to the continuous or non-continuous controls.

B. ***Measurement Equipment.*** The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section VI, and in addition electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. ***Test Conditions.*** The requirements regarding test conditions presented in section I.C of this appendix apply to this section VI. The following conditions also apply to the mains power supplied to the continuous or non-continuous control:

(1) Maintain the voltage within ±5 percent of the rated value of the motor,

(2) Maintain the frequency within ±1 percent of the rated value of the motor,

(3) Maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and

(4) Maintain total harmonic distortion below 12 percent throughout the test.

D. ***Testing BEP for the Pump.*** Determine the BEP of the pump as follows:

D.

1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6-2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see § 431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum overall efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6-2014 (incorporated by reference, see § 431.463), where overall efficiency is the ratio of the pump power output divided by the driver power input, as specified in Table 40.6.2.1 of HI 40.6-2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. ***Calculating the Variable Load Pump Energy Rating.*** Determine the PER_{VL} of each tested pump using the following equation:

$$PER_{VL} = \sum_{i=25\%,50\%75\%,100\%} \omega_i P_i^{in,c}$$

Where:

PER_{VL} = the pump energy rating for a variable load (hp);

ω_i = 0.25;

$P_i^{in,c}$ = the normalized driver power input to continuous or non-continuous controls at load point i for the tested pump as determined in accordance with section VI.E.1 of this appendix; and

i = load point corresponding 25, 50, 75, or 100 percent of the BEP flow rate.

E.

1. Determine the driver power input at 100 percent of the measured BEP flow rate of the tested pump by employing a least squares regression to determine a linear relationship between the measured driver power input at the nominal speed of rotation of the pump and the measured flow rate, using the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the driver power input at the nominal speed of rotation for the load point of 100 percent of the measured BEP flow rate of the tested pump.

E.2 Determine the driver power input at 25, 50, and 75 percent of the BEP flow rate by measuring the driver power input at the load points defined by:

(1) Those flow rates, and

(2) The associated head points calculated according to the following reference system curve equation:

$$H_i = \left(0.80 \times \frac{{Q_i}^2}{{Q_{100\%}}^2} + 0.20\right) \times H_{100\%}$$

Where:

H_i = pump total head at load point i (ft),

$H_{100\%}$ = pump total head at 100 percent of the BEP flow rate and nominal speed of rotation (ft),

Q_i = flow rate at load point i (gpm),

$Q_{100\%}$ = flow rate at 100 percent of the BEP flow rate and nominal speed of rotation (gpm), and

i = load point corresponding to 25, 50, or 75 percent of the measured BEP flow rate of the tested pump.

E.2.1. For pumps sold with motors and continuous controls, the specific head and flow points must be achieved within 10 percent of the calculated values and the measured driver power input must be corrected to the exact intended head and flow conditions using the following equation:

$$P_i^{in,c} = \left(\frac{H_{sp,i}}{H_{M,j}}\right)\left(\frac{Q_{sp,i}}{Q_{M,j}}\right) P_{M,j}^{in,c}$$

Where:

$P_i^{in,c}$ = the corrected driver power input to the continuous or non-continuous controls at load point i (hp),

$H_{sp,i}$ = the specified total system head at load point i based on the reference system curve (ft),

$H_{M,j}$ = the measured total system head at load point j (ft),

$Q_{sp,i}$ = the specified total system flow rate at load point i based on the reference system curve (gpm),

$Q_{M,j}$ = the measured total system flow rate at load point j (gpm),

$P_{M,j}^{in,c}$ = the measured normalized driver power input to the continuous or non-continuous controls at load point j (hp),

i = specified load point at 25, 50, 75, or 100 percent of BEP flow, and

j = measured load point corresponding to specified load point i.

E.2.2. For pumps sold with motors and non-continuous controls, the head associated with each of the specified flow points shall be no lower than 10 percent below that defined by the reference system curve equation in section VI.E.2 of this appendix. Only the measured flow points must be achieved within 10 percent of the calculated values. Correct for flow and head as described in section VI.E.2.1, except do not correct measured head values that are

higher than the reference system curve at the same flow rate; only correct flow rate and head values lower than the reference system curve at the same flow rate. For head values higher than the system curve, use the measured head points directly to calculate PEI_{VL}.

VII. Calculation-Based Approach for Pumps Sold With Motors and Controls

A. ***Scope.*** This section VII can only be used in lieu of the test method in section VI of this appendix to calculate the index for pumps listed in section VII.A.1 or VII.A.2 of this appendix.

A.

1. Pumps sold with motors regulated by DOE's energy conservation standards for polyphase NEMA Design B electric motors at § 431.25(g) and continuous controls, and

A.

2. Pumps sold with submersible motors and continuous controls.

A.3. Pumps sold with motors not listed in VII.A.1 or VII.A.2 of this appendix and pumps sold without continuous controls, including pumps sold with non-continuous controls, cannot use this section and must apply the test method in section VI of this appendix.

B. ***Measurement Equipment.*** The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section VII, and in addition, when testing pumps using a calibrated motor electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. ***Test Conditions.*** The requirements regarding test conditions presented in section I.C of this appendix apply to this section VII. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(1) Maintain the voltage within ±5 percent of the rated value of the motor,

(2) Maintain the frequency within ±1 percent of the rated value of the motor,

(3) Maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and

(4) Maintain total harmonic distortion below 12 percent throughout the test.

D. ***Testing BEP for the Bare Pump.*** Determine the BEP of the pump as follows:

D.

1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6-2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see § 431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6-2014 (incorporated by reference, see § 431.463), where pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6-2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. ***Calculating the Variable Load Pump Energy Rating.*** Determine the PER_{VL} of each tested pump using the following equation:

$$PER_{VL} = \sum_{i=25\%,50\%,75\%,100\%} \omega_i P_i^{in,c}$$

Where:

PER_{VL} = the pump energy rating for a variable load (hp);

ω_i = 0.25;

$P_i^{in,c}$ = the calculated driver power input to the continuous or non-continuous controls at load point i for the tested pump as determined in accordance with section VII.E.1 of this appendix; and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E. 1 Determine the driver power input at each load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate as follows:

$$P_i^{in,c} = P_i + L_i$$

Where:

$P_i^{in,c}$ = driver power input at to the continuous or non-continuous controls at load point i (hp),

P_i = pump power input to the bare pump at load point i as determined in accordance with section VII.E.1.1 of this appendix (hp),

L_i = the part load motor and control losses at load point i as determined in accordance with section VII.E.1.2 of this appendix (hp), and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E. 1.1 Determine the pump power input at 100 percent of the measured BEP flow rate of the tested pump by employing a least squares regression to determine a linear relationship between the measured pump power input at the nominal speed of rotation and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load point of 100 percent of the BEP flow rate.

E. 1.1.1 Determine the pump power input at 25, 50, and 75 percent of the BEP flow rate based on the measured pump power input at 100 percent of the BEP flow rate and using with the following equation:

$$P_i = \left(0.80 \times \frac{Q_i^{\,3}}{Q_{100\%}^{\,3}} + 0.20 \times \frac{Q_i}{Q_{100\%}}\right) \times P_{100\%}$$

Where:

P_i = pump power input at load point i (hp);

$P_{100\%}$ = pump power input at 100 percent of the BEP flow rate and nominal speed of rotation (hp);

Q_i = flow rate at load point i (gpm);

$Q_{100\%}$ = flow rate at 100 percent of the BEP flow rate and nominal speed of rotation (gpm); and

i = load point corresponding to 25, 50, or 75 percent of the measured BEP flow rate of the tested pump.

E. 1.2 Calculate the motor and control part load losses at each load point corresponding to 25, 50, 75, and 100 percent of the BEP flow rate as follows:

$L_i = L_{full} \times z_i$

Where:

L_i = motor and control losses at load point i (hp),

L_{full} = motor losses at full load as determined in accordance with section VII.E.1.2.1 of this appendix (hp),

z_i = part load loss factor at load point i as determined in accordance with section VII.E.1.2.2 of this appendix, and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E. 1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/_{100}\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp), and

$\eta_{motor,full}$ = the represented nominal full load motor efficiency (*i.e.,* nameplate/DOE-certified value) or default nominal full load submersible motor efficiency as determined in accordance with section VII.E.1.2.1.1 of this appendix (%).

E. 1.2.1.1 For pumps sold with motors other than submersible motors, determine the represented nominal full load motor efficiency as described in section VII.E.1.2.1.1.1 of this appendix. For pumps sold with submersible motors, determine the default nominal full load submersible motor efficiency as described in section VII.E.1.2.1.1.2 of this appendix.

E. 1.2.1.1.1 For pumps sold with motors other than submersible motors, the represented nominal full load motor efficiency is that of the motor with which the given pump model is being tested, as determined in accordance with the DOE test procedure for electric motors at § 431.16 and applicable representation procedures in parts 429 and 430.

E. 1.2.1.1.2 For pumps sold with submersible motors, the default nominal full load submersible motor efficiency is that listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower of the pump being tested.

E. 1.2.2 For load points corresponding to 25, 50, 75, and 100 percent of the BEP flow rate, determine the part load loss factor at each load point as follows:

$$z_i = a \times \left(\frac{P_i}{MotorHP}\right)^2 + b \times \left(\frac{P_i}{MotorHP}\right) + c$$

Where:

z_i = the motor and control part load loss factor at load point i,

a,b,c = coefficients listed in Table 4 of this appendix based on the horsepower of the motor with which the pump is being tested,

P_i = the pump power input to the bare pump at load point i, as determined in accordance with section VII.E.1.1 of this appendix (hp),

MotorHP = the horsepower of the motor with which the pump is being tested (hp),

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$ then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section VII.E.1.2.2 of this appendix to calculate the part load loss factor at load point i.

Table 2 - Default Nominal Full Load Submersible Motor Efficiency by Motor Horsepower and Pole

Motor horsepower (hp)	Default nominal full load submersible motor efficiency	
	2 poles	4 poles
1	55	68
1.5	66	70
2	68	70
3	70	75.5
5	74	75.5
7.5	68	74
10	70	74
15	72	75.5
20	72	77
25	74	78.5
30	77	80
40	78.5	81.5
50	80	82.5
60	81.5	84
75	81.5	85.5
100	81.5	84
125	84	84
150	84	85.5
200	85.5	86.5
250	86.5	86.5

Table 3 - Nominal Full Load Motor Efficiency Values

Nominal full load motor efficiency*
50.5
52.5
55.0
57.5
59.5
62.0
64.0
66.0
68.0
70.0
72.0
74.0

Nominal full load motor efficiency*
75.5
77.0
78.5
80.0
81.5
82.5
84.0
85.5
86.5
87.5
88.5
89.5
90.2
91.0
91.7
92.4
93.0
93.6
94.1
94.5
95.0
95.4
95.8
96.2
96.5
96.8
97.1
97.4
97.6
97.8
98.0
98.2
98.4
98.5
98.6
98.7
98.8
98.9
99.0

* **Note:** Each consecutive incremental value of nominal efficiency represents one band.

Table 4 - Motor and Control Part Load Loss Factor Equation Coefficients for Section VII.E.1.2.2 of This Appendix A

Motor horsepower (hp)	Coefficients for Motor and Control Part Load Loss Factor (z_i)		
	a	b	c
≤5	− 0.4658	1.4965	0.5303
>5 and ≤20	− 1.3198	2.9551	0.1052
>20 and ≤50	− 1.5122	3.0777	0.1847
>50	− 0.8914	2.8846	0.2625

[81 FR 4145, Jan. 25, 2016, as amended at 82 FR 36924, Aug. 7, 2017]