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ANNEXES 1 to 4

ANNEXES

to the

COMMISSION REGULATION

laying down ecodesign requirements for electric motors and variable speed drives pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Regulation (EC) No 641/2009 with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products

and repealing Commission Regulation (EC) No 640/2009

{SEC(2019) 334 final} - {SWD(2019) 343 final} - {SWD(2019) 344 final}

ECODESIGN REQUIREMENTS FOR MOTORS AND VARIABLE SPEED DRIVES**1. ENERGY EFFICIENCY REQUIREMENTS FOR MOTORS**

Energy efficiency requirements for motors shall apply according to the following timetable:

- (a) from 1 July 2021:
- (i) the energy efficiency of three-phase motors with a rated output equal to or above 0,75 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, which are not Ex eb increased safety motors, shall correspond to at least the IE3 efficiency level set out in Table 2;
 - (ii) the energy efficiency of three-phase motors with a rated output equal to or above 0,12 kW and below 0,75 kW, with 2, 4, 6 or 8 poles, which are not Ex eb increased safety motors, shall correspond to at least the IE2 efficiency level set out in Table 1;
- (b) from 1 July 2023:
- (i) the energy efficiency of Ex eb increased safety motors with a rated output equal to or above 0,12 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, and single-phase motors with a rated output equal to or above 0,12 kW shall correspond to at least the IE2 efficiency level set out in Table 1;
 - (ii) the energy efficiency of three-phase motors which are not brake motors, Ex eb increased safety motors, or other explosion-protected motors, with a rated output equal to or above 75 kW and equal to or below 200 kW, with 2, 4, or 6 poles, shall correspond to at least the IE4 efficiency level set out in Table 3.

Energy efficiency for motors, expressed in International Energy efficiency classes (IE), is set out in Tables 1, 2 and 3, for different values of the motor rated output power P_N . IE classes are determined at rated output power (P_N), rated voltage (U_N), based on the 50 Hz operation and 25 °C ambient reference temperature.

Table 1: Minimum efficiencies η_n for IE2 efficiency level at 50 Hz (%)

Rated output power P_N [kW]	Number of poles			
	2	4	6	8
0,12	53,6	59,1	50,6	39,8
0,18	60,4	64,7	56,6	45,9
0,20	61,9	65,9	58,2	47,4
0,25	64,8	68,5	61,6	50,6
0,37	69,5	72,7	67,6	56,1
0,40	70,4	73,5	68,8	57,2
0,55	74,1	77,1	73,1	61,7
0,75	77,4	79,6	75,9	66,2
1,1	79,6	81,4	78,1	70,8
1,5	81,3	82,8	79,8	74,1
2,2	83,2	84,3	81,8	77,6
3	84,6	85,5	83,3	80,0
4	85,8	86,6	84,6	81,9
5,5	87,0	87,7	86,0	83,8

7,5	88,1	88,7	87,2	85,3
11	89,4	89,8	88,7	86,9
15	90,3	90,6	89,7	88,0
18,5	90,9	91,2	90,4	88,6
22	91,3	91,6	90,9	89,1
30	92,0	92,3	91,7	89,8
37	92,5	92,7	92,2	90,3
45	92,9	93,1	92,7	90,7
55	93,2	93,5	93,1	91,0
75	93,8	94,0	93,7	91,6
90	94,1	94,2	94,0	91,9
110	94,3	94,5	94,3	92,3
132	94,6	94,7	94,6	92,6
160	94,8	94,9	94,8	93,0
200 up to 1 000	95,0	95,1	95,0	93,5

Table 2: Minimum efficiencies η_n for IE3 efficiency level at 50 Hz (%)

Rated output power P_N [kW]	Number of poles			
	2	4	6	8
0,12	60,8	64,8	57,7	50,7
0,18	65,9	69,9	63,9	58,7
0,20	67,2	71,1	65,4	60,6
0,25	69,7	73,5	68,6	64,1
0,37	73,8	77,3	73,5	69,3
0,40	74,6	78,0	74,4	70,1
0,55	77,8	80,8	77,2	73,0
0,75	80,7	82,5	78,9	75,0
1,1	82,7	84,1	81,0	77,7
1,5	84,2	85,3	82,5	79,7
2,2	85,9	86,7	84,3	81,9
3	87,1	87,7	85,6	83,5
4	88,1	88,6	86,8	84,8
5,5	89,2	89,6	88,0	86,2
7,5	90,1	90,4	89,1	87,3
11	91,2	91,4	90,3	88,6
15	91,9	92,1	91,2	89,6
18,5	92,4	92,6	91,7	90,1
22	92,7	93,0	92,2	90,6
30	93,3	93,6	92,9	91,3
37	93,7	93,9	93,3	91,8
45	94,0	94,2	93,7	92,2
55	94,3	94,6	94,1	92,5
75	94,7	95,0	94,6	93,1
90	95,0	95,2	94,9	93,4

110	95,2	95,4	95,1	93,7
132	95,4	95,6	95,4	94,0
160	95,6	95,8	95,6	94,3
200 up to 1 000	95,8	96,0	95,8	94,6

Table 3: Minimum efficiencies η_n for IE4 efficiency level 50 Hz (%)

Rated output power P_N [kW]	Number of poles			
	2	4	6	8
0,12	66,5	69,8	64,9	62,3
0,18	70,8	74,7	70,1	67,2
0,20	71,9	75,8	71,4	68,4
0,25	74,3	77,9	74,1	70,8
0,37	78,1	81,1	78,0	74,3
0,40	78,9	81,7	78,7	74,9
0,55	81,5	83,9	80,9	77,0
0,75	83,5	85,7	82,7	78,4
1,1	85,2	87,2	84,5	80,8
1,5	86,5	88,2	85,9	82,6
2,2	88,0	89,5	87,4	84,5
3	89,1	90,4	88,6	85,9
4	90,0	91,1	89,5	87,1
5,5	90,9	91,9	90,5	88,3
7,5	91,7	92,6	91,3	89,3
11	92,6	93,3	92,3	90,4
15	93,3	93,9	92,9	91,2
18,5	93,7	94,2	93,4	91,7
22	94,0	94,5	93,7	92,1
30	94,5	94,9	94,2	92,7
37	94,8	95,2	94,5	93,1
45	95,0	95,4	94,8	93,4
55	95,3	95,7	95,1	93,7
75	95,6	96,0	95,4	94,2
90	95,8	96,1	95,6	94,4
110	96,0	96,3	95,8	94,7
132	96,2	96,4	96,0	94,9
160	96,3	96,6	96,2	95,1
200 up to 249	96,5	96,7	96,3	95,4
250 up to 314	96,5	96,7	96,5	95,4
315 up to 1 000	96,5	96,7	96,6	95,4

To determine the minimum efficiency of 50 Hz motors with rated power outputs P_N of between 0,12 and 200 kW not provided in Tables 1, 2 and 3, the following formula shall be used:

$$\eta_n = A \times [\log_{10}(P_N/1kW)]^3 + B \times [\log_{10}(P_N/1kW)]^2 + C \times \log_{10}(P_N/1kW) + D$$

A, B, C and D are interpolation coefficients to be determined according to Tables 4 and 5.

Table 4: Interpolation coefficients for motors with rated power output P from 0,12 kW up to 0,55 kW

IE code	Coefficients	2 poles	4 poles	6 poles	8 poles
IE2	A	22,4864	17,2751	-15,9218	6,4855
	B	27,7603	23,978	-30,258	9,4748
	C	37,8091	35,5822	16,6861	36,852
	D	82,458	84,9935	79,1838	70,762
IE3	A	6,8532	7,6356	-17,361	-0,5896
	B	6,2006	4,8236	-44,538	-25,526
	C	25,1317	21,0903	-3,0554	4,2884
	D	84,0392	86,0998	79,1318	75,831
IE4	A	-8,8538	8,432	-13,0355	-4,9735
	B	-20,3352	2,6888	-36,9497	-21,453
	C	8,9002	14,6236	-4,3621	2,6653
	D	85,0641	87,6153	82,0009	79,055

Between 0,55 kW and 0,75 kW, a linear interpolation shall be performed on the obtained minimum efficiencies for 0,55 kW and 0,75 kW.

Table 5: Interpolation coefficients for motors with rated power output P from 0,75 kW up to 200 kW

IE code	Coefficients	2 poles	4 poles	6 poles	8 poles
IE2	A	0,2972	0,0278	0,0148	2,1311
	B	-3,3454	-1,9247	-2,4978	-12,029
	C	13,0651	10,4395	13,247	26,719
	D	79,077	80,9761	77,5603	69,735
IE3	A	0,3569	0,0773	0,1252	0,7189
	B	-3,3076	-1,8951	-2,613	-5,1678
	C	11,6108	9,2984	11,9963	15,705
	D	82,2503	83,7025	80,4769	77,074
IE4	A	0,34	0,2412	0,3598	0,6556
	B	-3,0479	-2,3608	-3,2107	-4,7229
	C	10,293	8,446	10,7933	13,977
	D	84,8208	86,8321	84,107	80,247

Losses are determined in accordance with Annex II.

2. PRODUCT INFORMATION REQUIREMENTS FOR MOTORS

The product information requirements set out in points (1) to (13) below shall be visibly displayed on:

- (a) the technical data sheet or user manual supplied with the motor;
- (b) the technical documentation for the purposes of conformity assessment pursuant to Article 5;
- (c) free access websites of the manufacturer of the motor, its authorised representative or the importer, and;
- (d) the technical data sheet supplied with products in which the motor is incorporated.

As regards to the technical documentation, the information shall be provided in the order as set out in points (1) to (13). The exact wording used in the list does not need to be repeated. The information may be displayed using clearly understandable graphs figures or symbols rather than text.

From 1 July 2021:

- (1) rated efficiency (η_N) at the full, 75 % and 50 % rated load and voltage (U_N), determined based on the 50 Hz operation and 25 °C ambient reference temperature, rounded to one decimal place;
- (2) efficiency level: 'IE2' 'IE3' or 'IE4', as determined in the first section of this Annex;
- (3) manufacturer's name or trade mark, commercial registration number and address;
- (4) product's model identifier;
- (5) number of poles of the motor;
- (6) the rated power output(s) P_N or range of rated power output (kW);
- (7) the rated input frequency(s) of the motor (Hz);
- (8) the rated voltage(s) or range of rated voltage (V);
- (9) the rated speed(s) or range of rated speed (rpm);
- (10) whether single-phase or three-phase;
- (11) information on the range of operating conditions for which the motor is designed:
 - (a) altitudes above sea-level;
 - (b) minimum and maximum ambient air temperatures including for motors with air cooling;
 - (c) water coolant temperature at the inlet to the product, where applicable;
 - (d) maximum operating temperature;
 - (e) potentially explosive atmospheres;
- (12) if the motor is considered exempt from efficiency requirement in accordance with Article 2(2) of this Regulation, the specific reason why it is considered exempt.

From 1 July 2022:

- (13) The power losses expressed in percentage (%) of the rated output power at the following different operating points for speed versus torque: (25;25) (25;100) (50;25) (50;50) (50;100) (90;50) (90;100) determined based on 25 °C ambient reference temperature, rounded to one decimal place; if the motor is not suited for operation at any of the operating points for speed versus torque above, then 'N.A.' or 'Not Applicable' should be indicated for such points.

The information referred to in points (1) and (2) as well as the year of manufacture shall be durably marked on or near the rating plate of the motor. Where the size of the rating plate makes it impossible to mark all the information referred to in point (1) only the rated efficiency at full rated load and voltage shall be marked.

The information listed in points (1) to (13) does not need to be published on free access websites for tailor-made motors with a special mechanical and electrical design manufactured

on the basis of a specific client request if this information is included in the commercial offers provided to the clients.

Manufacturers shall provide information in the technical data sheet or user manual supplied with the motor on any specific precautions that must be taken when motors are assembled, installed, maintained or used with variable speed drives.

For motors exempt from the efficiency requirements in accordance with point 2(m) of Article 2 of this Regulation, the motor or its packaging and the documentation must clearly indicate ‘Motor to be used exclusively as spare part for’ and the product(s) for which it is intended.

For 50/60 Hz and 60 Hz motors, the information set out in points (1) and (2) above may be provided for the 60 Hz operation in addition to the values at 50 Hz, with clear indication of the applicable frequencies.

Losses are determined in accordance with Annex II.

3. EFFICIENCY REQUIREMENTS FOR VARIABLE SPEED DRIVES

Efficiency requirements for variable speed drives shall apply as follows:

From 1 July 2021, the power losses of variable speed drives rated for operating with motors with a rated output power equal to or above 0,12 kW and equal to or below 1 000 kW shall not exceed the maximum power losses corresponding to the IE2 efficiency level.

Energy efficiency for VSDs, expressed in International Energy efficiency classes (IE), is determined based on the power losses as follows:

The maximum power losses of the IE2 class are 25 % lower than the reference value referred to in Table 6.

Table 6 – Reference VSD losses and test load displacement factor for the IE class determination of VSDs

Apparent output power of VSD (kVA)	Rated power of Motor (kW) (indicative)	Reference power losses (kW), at 90% rated motor stator frequency and 100% rated torque-producing current	Test load displacement factor cos phi (+/- 0,08)
0,278	0,12	0,100	0,73
0,381	0,18	0,104	0,73
0,500	0,25	0,109	0,73
0,697	0,37	0,117	0,73
0,977	0,55	0,129	0,73
1,29	0,75	0,142	0,79
1,71	1,1	0,163	0,79
2,29	1,5	0,188	0,79
3,3	2,2	0,237	0,79
4,44	3	0,299	0,79
5,85	4	0,374	0,79
7,94	5,5	0,477	0,85
9,95	7,5	0,581	0,85
14,4	11	0,781	0,85
19,5	15	1,01	0,85

23,9	18,5	1,21	0,85
28,3	22	1,41	0,85
38,2	30	1,86	0,85
47	37	2,25	0,85
56,9	45	2,70	0,86
68,4	55	3,24	0,86
92,8	75	4,35	0,86
111	90	5,17	0,86
135	110	5,55	0,86
162	132	6,65	0,86
196	160	8,02	0,86
245	200	10,0	0,87
302	250	12,4	0,87
381	315	15,6	0,87
429	355	17,5	0,87
483	400	19,8	0,87
604	500	24,7	0,87
677	560	27,6	0,87
761	630	31,1	0,87
858	710	35,0	0,87
967	800	39,4	0,87
1 088	900	44,3	0,87
1 209	1 000	49,3	0,87

If the apparent output power of a VSD is between two values in Table 6, the higher power loss value and the lower value of the test load displacement factor shall be used for the IE class determination.

Losses are determined in accordance with Annex II.

4. PRODUCT INFORMATION REQUIREMENTS FOR VARIABLE SPEED DRIVES

From 1 July 2021, the product information on variable speed drives set out in points (1) to (11) shall be visibly displayed on:

- (a) the technical data sheet or user manual supplied with the VSD;
- (b) the technical documentation for the purposes of conformity assessment pursuant to Article 5;
- (c) free access websites of the manufacturer, its authorised representative or the importer and;
- (d) the technical data sheet supplied with products in which the VSD is incorporated.

As regards to the technical documentation, the information shall be provided in the order as listed in points (1) to (11). The exact wording used in the list does not need to be repeated. It may be displayed using clearly understandable graphs figures or symbols rather than text:

- (1) power losses in % of the rated apparent output power at the following different operating points for relative motor stator frequency versus relative torque-producing current (0;25) (0;50) (0;100) (50;25) (50;50) (50;100) (90;50) (90;100), as well as

standby losses, generated when the VSD is powered up but is not providing current to the load, rounded to one decimal place;

- (2) efficiency level: 'IE2' as determined in the third section of this annex;
- (3) manufacturer's name or trade mark, commercial registration number and address;
- (4) product's model identifier;
- (5) apparent output power or range of apparent output power (kVA);
- (6) indicative motor rated power output(s) P_N or range of rated power output (kW);
- (7) rated output current (A);
- (8) maximum operating temperature (°C);
- (9) rated supply frequency(s) (Hz);
- (10) rated supply voltage(s) or range of rated supply voltage (V);
- (11) if the VSD is considered exempt from the efficiency requirements in accordance with Article 2(3) of this Regulation the specific reason why it is considered exempt.

The information listed above in points (1) to (11) does not need to be published on free access websites for tailor-made VSDs with special electrical design manufactured on the basis of a specific client request if this information is included in the commercial offers provided to the clients.

The information referred to in points (1) and (2) as well as the year of manufacture shall be durably marked on or near the rating plate of the VSD. Where the size of the rating plate makes it impossible to mark all the information referred to in point (1) only the rated efficiency at (90;100) shall be marked.

Losses are determined in accordance with Annex II.

ANNEX II
MEASUREMENT METHODS AND CALCULATIONS

For the purposes of compliance and verification of compliance with the requirements of this Regulation, measurements and calculations shall be made using harmonised standards the reference numbers of which have been published for this purpose in the *Official Journal of the European Union*, or other reliable, accurate and reproducible methods, which take into account the generally recognised state-of-the-art, and in line with the following provisions:

1. FOR MOTORS

The difference between the output mechanical power and the input electrical power is due to losses occurring in the motor. Total losses shall be determined using the following methods, based on a 25 °C reference ambient temperature:

- Single-phase motors: Direct measurement: Input-Output;
- Three-phase motors: Summation of losses: Residual losses.

For 60 Hz motors, equivalent values of the rated output power (P_N) and rated voltage (U_N) for the 50 Hz operation shall be calculated based on the values applicable at 60 Hz.

2. FOR VARIABLE SPEED DRIVES

For the determination of the IE class, the power losses of VSDs shall be determined at 100 % rated torque-producing current and 90 % rated motor stator frequency.

The losses shall be determined according to one of the following methods:

- the input-output method; or
- the calorimetric method.

The test switching frequency shall be 4 kHz until 111 kVA (90 kW) and 2 kHz above, or at the default factory settings as defined by the manufacturer.

It is acceptable to measure VSD losses at a frequency of up to 12 Hz instead of zero.

Manufacturers or their authorised representatives can also use the single loss determination method. Calculations have to be performed with respect to component manufacturer's data with typical values of power semiconductors at the actual VSD operating temperature or at the maximum operating temperature specified in the datasheet. When no component manufacturer data is available, losses shall be determined by measurement. Combination of calculated and measured losses are allowed. The different individual losses are calculated or measured separately and the total losses are determined as the sum of all individual losses.

ANNEX III

VERIFICATION PROCEDURE FOR MARKET SURVEILLANCE PURPOSES

The verification tolerances defined in this Annex relate only to the verification of the measured parameters by Member State authorities and shall not be used by the manufacturer, importer or authorised representative as an allowed tolerance to establish the values in the technical documentation or in interpreting these values with a view to achieving compliance or to communicate better performance by any means.

Where a model has been designed to be able to detect it is being tested (e.g. by recognizing the test conditions or test cycle), and to react specifically by automatically altering its performance during the test with the objective of reaching a more favourable level for any of the parameters specified in this Regulation or included in the technical documentation or included in any of the documentation provided, the model and all equivalent models shall be considered not compliant.

When verifying that a product model complies with the requirements laid down in this Regulation pursuant to Article 3(2) of Directive 2009/125/EC the authorities of the Member States shall apply the following procedure for the requirements referred to in Annex I.

- (1) The Member State authorities shall verify one single unit of the model.
- (2) The model shall be considered to comply with the applicable requirements if:
 - (a) the values given in the technical documentation pursuant to point 2 of Annex IV to Directive 2009/125/EC (declared values) and where applicable the values used to calculate these values are not more favourable for the manufacturer, importer or authorised representative than the results of the corresponding measurements carried out pursuant to point (g) thereof; and
 - (b) the declared values meet any requirements laid down in this Regulation and any required product information published by the manufacturer, importer or authorised representative does not contain values that are more favourable for the manufacturer, importer or authorised representative than the declared values; and
 - (c) when the Member State authorities test the unit of the model, the determined values (the values of the relevant parameters as measured in testing and the values calculated from these measurements) comply with the respective verification tolerances as set out in Table 7.
- (3) If the results referred to in points (2)(a) or (2)(b) are not achieved the model and all equivalent models shall be considered not to comply with this Regulation.
- (4) If the result referred to in point (2)(c) is not achieved;
 - (a) for models that are produced in quantities of less than five per year including equivalent models, the model and all equivalent models shall be considered not to comply with this Regulation;
 - (b) for models that are produced in quantities of five or more per year including equivalent models, the Member State authorities shall select three additional units of the same model for testing. As an alternative, the three additional units selected may be one or more of equivalent models.
- (5) The model shall be considered to comply with the applicable requirements if for these three units the arithmetical mean of the determined values complies with the respective verification tolerances given in Table 7.

- (6) If the result referred to in point (5) is not achieved the model and all equivalent models shall be considered not to comply with this Regulation.
- (7) The Member State authorities shall provide all relevant information to the authorities of the other Member States and to the Commission without delay after a decision is taken on the non-compliance of the model according to points (3) or (6).

The Member State authorities shall use the measurement and calculation methods set out in Annex II.

Given the weight and size limitations for the transportation of motors with a rated power output of 375 to 1 000 kW Member States authorities may decide to undertake the verification procedure at the premises of manufacturers, authorised representatives or importers before the products are put into service. The Member State authority can do this verification using its own testing equipment.

If factory acceptance tests are planned for such motors, which will test parameters laid down in Annex I of this Regulation, the Member State authorities may decide to use witnessed testing during these factory acceptance tests to gather test results which can be used to verify compliance of the motor under investigation. The authorities may request a manufacturer, authorised representative or importer to disclose information on any planned factory acceptance tests relevant for witnessed testing.

In the cases mentioned in the two paragraphs above, the Member States authorities only need to verify one single unit of the model. If the result referred to in point 2(c) is not achieved, the model and all equivalent models shall be considered not to comply with this regulation.

The Member State authorities shall only apply the tolerances set out in Table 7 and shall only use the procedure described in points (1) to (7) for the requirements referred to in this Annex. For the parameters in Table 7, no other tolerances such as those set out in harmonised standards or in any other measurement method shall be applied.

Table 7 — Verification tolerances	
<i>Parameters</i>	<i>Verification tolerances</i>
Total losses (1- η) for motors with a rated output equal to or above 0,12 kW and equal to or below 150 kW.	The determined value* shall not exceed the value (1- η) calculated based on the declared η by more than 15 %.
Total losses (1- η) for motors with a rated output of above 150 kW and equal to or below 1 000 kW.	The determined value* shall not exceed the value (1- η) calculated based on the declared η by more than 10 %.
Total losses for variable speed drives.	The determined value* shall not exceed the declared value by more than 10 %.

* In the case of three additional units tested as prescribed in point 4 (b), the determined value means the arithmetical mean of the values determined for these three additional units.

ANNEX IV
BENCHMARKS

At the time of adoption of this Regulation the best available technology on the market for the environmental aspects that were considered significant and are quantifiable is indicated below.

For motors the IE4 level was identified as the best available technology. Motors with losses that are 20 % lower exist but within limited availability and not in all power ranges covered by this Regulation and not in the form of induction motors.

For variable speed drives, the best available technology on the market corresponds to 20 % of the reference power losses referred to in Table 6. By utilising silicon carbide technologies (SiC MOFSET), semiconductor losses could be further reduced by about 50 % compared to a conventional solution.