



**COMMISSION REGULATION (EU) No 548/2014****of 21 May 2014****on implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers***Article 1***Subject matter and scope**

1. This Regulation establishes ecodesign requirements for placing on the market or putting into service power transformers with a minimum power rating of 1 kVA used in 50 Hz electricity transmission and distribution networks or for industrial applications. The Regulation is only applicable to transformers purchased after the entry into force of the Regulation.

2. This Regulation shall not apply to transformers specifically designed and used for the following applications:

- instrument transformers, specifically designed to supply measuring instruments, meters, relays and other similar apparatus,
- transformers with low-voltage windings specifically designed for use with rectifiers to provide a DC supply,
- transformers specifically designed to be directly connected to a furnace,
- transformers specifically designed for offshore applications and floating offshore applications,
- transformers specially designed for emergency installations,
- transformers and auto-transformers specifically designed for railway feeding systems,
- earthing or grounding transformers, this is, three-phase transformers intended to provide a neutral point for system grounding purposes,
- traction transformers mounted on rolling stock, this is, transformers connected to an AC or DC contact line, directly or through a converter, used in fixed installations of railway applications,
- starting transformers, specifically designed for starting three-phase induction motors so as to eliminate supply voltage dips,
- testing transformers, specifically designed to be used in a circuit to produce a specific voltage or current for the purpose of testing electrical equipment,
- welding transformers, specifically designed for use in arc welding equipment or resistance welding equipment,

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- transformers specifically designed for explosion-proof and underground mining applications <sup>(1)</sup>,
- transformers specifically designed for deep water (submerged) applications,
- medium Voltage (MV) to Medium Voltage (MV) interface transformers up to 5 MVA,
- large power transformers where it is demonstrated that for a particular application, technically feasible alternatives are not available to meet the minimum efficiency requirements set out by this Regulation,
- large power transformers which are like for like replacements in the same physical location/installation for existing large power transformers, where this replacement cannot be achieved without entailing disproportionate costs associated to their transportation and/or installation,

except as regards the product information requirements and technical documentation set out in Annex I, points 3 and 4.

*Article 2***Definitions**

For the purpose of this Regulation and its annexes the following definitions shall apply.

- (1) ‘Power transformer’ means a static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of alternating voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.
- (2) ‘Small power transformer’ means a power transformer with a highest voltage for equipment not exceeding 1,1 kV.
- (3) ‘Medium power transformer’ means a power transformer with a highest voltage for equipment higher than 1,1 kV, but not exceeding 36 kV and a rated power equal to or higher than 5 kVA but lower than 40 MVA.
- (4) ‘Large power transformer’ means a power transformer with a highest voltage for equipment exceeding 36 kV and a rated power equal or higher than 5 kVA, or a rated power equal to or higher than 40 MVA regardless of the highest voltage for equipment.
- (5) ‘Liquid-immersed transformer’ means a power transformer in which the magnetic circuit and windings are immersed in liquid.
- (6) ‘Dry-type transformer’ means a power transformer in which the magnetic circuit and windings are not immersed in an insulating liquid.

<sup>(1)</sup> Equipment intended for use in potentially explosive atmospheres is covered by Directive 94/9/EC of the European Parliament and of the Council (OJ L 100, 19.4.1994, p. 1).

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- (7) ‘Medium power pole mounted transformer’ means a power transformer with a rated power of up to 315 kVA suitable for outdoor service and designed to be mounted on the support structures of overhead power lines.
- (8) ‘Voltage Regulation Distribution Transformer’ means a medium power transformer equipped with additional components, inside or outside of the transformer tank, to automatically control the input or output voltage of the transformer for on-load voltage regulation purposes.
- (9) ‘Winding’ refers to the assembly of turns forming an electrical circuit associated with one of the voltages assigned to the transformer.
- (10) ‘Rated voltage of a winding’ ( $U_r$ ) is the voltage assigned to be applied, or developed at no-load, between the terminals of an untapped winding, or of a tapped winding connected on the principal tapping.
- (11) ‘High-voltage winding’ refers to the winding having the highest rated voltage.
- (12) ‘Highest voltage for equipment’ ( $U_m$ ) applicable to a transformer winding is the highest r.m.s phase-to-phase voltage in a three-phase system for which a transformer winding is designed in respect of its insulation.
- (13) ‘Rated power’ ( $S_r$ ) is a conventional value of apparent power assigned to a winding which, together with the rated voltage of the winding, determines its rated current.
- (14) ‘Load loss’ ( $P_k$ ) means the absorbed active power at rated frequency and reference temperature associated with a pair of windings when the rated current (tapping current) is flowing through the line terminal(s) of one of the windings and the terminals of the other windings are in short-circuit with any winding fitted with tapplings connected to its principal tapping, while further windings, if existing, are open-circuited.
- (15) ‘No load loss’ ( $P_o$ ) means the active power absorbed at rated frequency when the transformer is energised and the secondary circuit is open. The applied voltage is the rated voltage, and if the energized winding is fitted with a tapping, it is connected to its principal tapping.
- (16) ‘Peak Efficiency Index’ (PEI) means the maximum value of the ratio of the transmitted apparent power of a transformer minus the electrical losses to the transmitted apparent power of the transformer.

*Article 3***Eco-design requirements**

Small power transformers, medium power transformers and large power transformer shall meet the ecodesign requirements set out in Annex I.

**▼B***Article 4***Conformity Assessment**

Conformity assessment shall be carried out applying the internal design control procedure set out in Annex IV to Directive 2009/125/EC or the management system procedure set out in Annex V to that Directive.

*Article 5***Verification procedure for market surveillance purposes**

When performing the market surveillance checks referred to in Directive 2009/125/EC, Article 3(2), Member State authorities shall apply the verification procedure set out in Annex III to this Regulation.

*Article 6***Indicative Benchmarks**

The indicative benchmarks for the best-performing transformers technologically possible at the time of adoption of this Regulation are identified in Annex IV.

*Article 7***Review**

No later than three years after the entry into force, the Commission shall review this Regulation in the light of technological progress and present the results of this review to the Consultation Forum. Specifically, the review will assess, at least, the following issues:

- the possibility to set out minimum values of the Peak Efficiency Index for all medium power transformers, including those with a rated power below 3 150 kVA,
- the possibility to separate the losses associated to the core transformer from those associated with other components performing voltage regulation functions, where this is the case,
- the appropriateness of establishing minimum performance requirements for single-phase power transformers, as well as for small power transformers,
- whether concessions made for pole-mounted transformers and for special combinations of winding voltages for medium power transformers are still appropriate,
- the possibility of covering environmental impacts other than energy in the use phase.

*Article 8***Entry into force**

The Regulation shall enter into force on the 20<sup>th</sup> day following its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.



## ANNEX I

## Ecodesign requirements

## 1. Minimum energy performance or efficiency requirements for medium power transformers

Medium power transformers shall comply with the maximum allowed load and no-load losses or the Peak Efficiency Index (PEI) values set out in Tables I.1 to I.5, excluding medium power pole-mounted transformers, which shall comply with the maximum allowed load and no load losses values set out in Table I.6.

1.1. Requirements for three-phase medium power transformers with rated power  $\leq 3\,150$  kVA

Table I.1: Maximum load and no-load losses (in W) for three-phase **liquid-immersed** medium power transformers with one winding with  $U_m \leq 24$  kV and the other one with  $U_m \leq 1,1$  kV

Rated Power (kVA)	Tier 1 (from 1 July 2015)		Tier 2 (from 1 July 2021)	
	Maximum load losses $P_k$ (W) (*)	Maximum no-load losses $P_o$ (W) (*)	Maximum load losses $P_k$ (W) (*)	Maximum no-load losses $P_o$ (W) (*)
$\leq 25$	$C_k$ (900)	$A_o$ (70)	$A_k$ (600)	$A_o - 10\%$ (63)
50	$C_k$ (1 100)	$A_o$ (90)	$A_k$ (750)	$A_o - 10\%$ (81)
100	$C_k$ (1 750)	$A_o$ (145)	$A_k$ (1 250)	$A_o - 10\%$ (130)
160	$C_k$ (2 350)	$A_o$ (210)	$A_k$ (1 750)	$A_o - 10\%$ (189)
250	$C_k$ (3 250)	$A_o$ (300)	$A_k$ (2 350)	$A_o - 10\%$ (270)
315	$C_k$ (3 900)	$A_o$ (360)	$A_k$ (2 800)	$A_o - 10\%$ (324)
400	$C_k$ (4 600)	$A_o$ (430)	$A_k$ (3 250)	$A_o - 10\%$ (387)
500	$C_k$ (5 500)	$A_o$ (510)	$A_k$ (3 900)	$A_o - 10\%$ (459)
630	$C_k$ (6 500)	$A_o$ (600)	$A_k$ (4 600)	$A_o - 10\%$ (540)
800	$C_k$ (8 400)	$A_o$ (650)	$A_k$ (6 000)	$A_o - 10\%$ (585)
1 000	$C_k$ (10 500)	$A_o$ (770)	$A_k$ (7 600)	$A_o - 10\%$ (693)
1 250	$B_k$ (11 000)	$A_o$ (950)	$A_k$ (9 500)	$A_o - 10\%$ (855)
1 600	$B_k$ (14 000)	$A_o$ (1 200)	$A_k$ (12 000)	$A_o - 10\%$ (1 080)
2 000	$B_k$ (18 000)	$A_o$ (1 450)	$A_k$ (15 000)	$A_o - 10\%$ (1 305)
2 500	$B_k$ (22 000)	$A_o$ (1 750)	$A_k$ (18 500)	$A_o - 10\%$ (1 575)
3 150	$B_k$ (27 500)	$A_o$ (2 200)	$A_k$ (23 000)	$A_o - 10\%$ (1 980)

(\*) Maximum losses for kVA ratings that fall in between the ratings given in Table I.1 shall be obtained by linear interpolation.

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Table I.2: Maximum load and no-load losses (in W) for three –phase **dry-type** medium power transformers with one winding with  $U_m \leq 24$  kV and the other one with  $U_m \leq 1,1$  kV.

Rated Power (kVA)	Tier 1 (1 July 2015)		Tier 2 (1 July 2021)	
	Maximum load losses $P_k$ (W) (*)	Maximum no-load losses $P_o$ (W) (*)	Maximum load losses $P_k$ (W) (*)	Maximum no-load losses $P_o$ (W) (*)
$\leq 50$	$B_k$ (1 700)	$A_o$ (200)	$A_k$ (1 500)	$A_o - 10 \%$ (180)
100	$B_k$ (2 050)	$A_o$ (280)	$A_k$ (1 800)	$A_o - 10 \%$ (252)
160	$B_k$ (2 900)	$A_o$ (400)	$A_k$ (2 600)	$A_o - 10 \%$ (360)
250	$B_k$ (3 800)	$A_o$ (520)	$A_k$ (3 400)	$A_o - 10 \%$ (468)
400	$B_k$ (5 500)	$A_o$ (750)	$A_k$ (4 500)	$A_o - 10 \%$ (675)
630	$B_k$ (7 600)	$A_o$ (1 100)	$A_k$ (7 100)	$A_o - 10 \%$ (990)
800	$A_k$ (8 000)	$A_o$ (1 300)	$A_k$ (8 000)	$A_o - 10 \%$ (1 170)
1 000	$A_k$ (9 000)	$A_o$ (1 550)	$A_k$ (9 000)	$A_o - 10 \%$ (1 395)
1 250	$A_k$ (11 000)	$A_o$ (1 800)	$A_k$ (11 000)	$A_o - 10 \%$ (1 620)
1 600	$A_k$ (13 000)	$A_o$ (2 200)	$A_k$ (13 000)	$A_o - 10 \%$ (1 980)
2 000	$A_k$ (16 000)	$A_o$ (2 600)	$A_k$ (16 000)	$A_o - 10 \%$ (2 340)
2 500	$A_k$ (19 000)	$A_o$ (3 100)	$A_k$ (19 000)	$A_o - 10 \%$ (2 790)
3 150	$A_k$ (22 000)	$A_o$ (3 800)	$A_k$ (22 000)	$A_o - 10 \%$ (3 420)

(\*) Maximum losses for kVA ratings that fall in between the ratings given in Table I.2 shall be obtained by linear interpolation.

Table I.3: Correction of load and no load losses in case of other combinations of winding voltages or dual voltage in one or both windings (rated power  $\leq 3 150$  kVA)

One winding with $U_m \leq 24$ kV and the other with $U_m > 1,1$ kV	The maximum allowable losses in Tables I.1 and I.2 shall be increased by 10 % for no load losses and by 10 % for load losses
One winding with $U_m = 36$ kV and the other with $U_m \leq 1,1$ kV	The maximum allowable losses in Tables I.1 and I.2 shall be increased by 15 % for no load losses and by 10 % for load losses
One winding with $U_m = 36$ kV and the other with $U_m > 1,1$ kV	The maximum allowable losses indicated in Tables I.1 and I.2 shall be increased by 20 % for no load losses and by 15 % for load losses

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Case of dual voltage on one winding	In case of transformers with one high-voltage winding and two voltages available from a tapped low-voltage winding, losses shall be calculated based on the higher voltage of the low-voltage winding and shall be in compliance with the maximum allowable losses in Tables I.1 and I.2. The maximum available power on the lower voltage of the low-voltage winding on such transformers shall be limited to 0,85 of the rated power assigned to the low-voltage winding at its higher voltage.
	In case of transformers with one low-voltage winding with two voltages available from a tapped high-voltage winding, losses shall be calculated based on the higher voltage of the high-voltage winding and shall be in compliance with the maximum allowable losses in Tables I.1 and I.2., The maximum available power on the lower voltage of the high-voltage winding on such transformer shall be limited to 0,85 of the rated power assigned to the high-voltage winding at its higher voltage.
	If the full nominal power is available regardless of the combination of voltages, the levels of losses indicated in Tables I.1 and I.2 can be increased by 15 % for no load losses and by 10 % for load losses.
Case of dual voltage on both windings	The maximum allowable losses in Tables I.1 and I.2 can be increased by 20 % for no load losses and by 20 % for load losses for transformers with dual voltage on both windings. The level of losses is given for the highest possible rated power and on the basis that the rated power is the same regardless of the combination of voltages.

### 1.2. Requirements for medium power transformers with rated power > 3 150 kVA

Table I.4: Minimum Peak Efficiency Index (PEI) values for **liquid immersed** medium power transformers

Rated Power (kVA)	Tier 1 (1 July 2015)	Tier 2 (1 July 2021)
	Minimum Peak Efficiency Index (%)	
$3\,150 < S_r \leq 4\,000$	99,465	99,532
5 000	99,483	99,548
6 300	99,510	99,571
8 000	99,535	99,593
10 000	99,560	99,615
12 500	99,588	99,640
16 000	99,615	99,663
20 000	99,639	99,684
25 000	99,657	99,700
31 500	99,671	99,712
40 000	99,684	99,724



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Minimum PEI values for kVA ratings that fall in between the ratings given in Table I.4 shall be calculated by linear interpolation.

Table I.5: Minimum Peak Efficiency Index (PEI) values for **dry type** medium power transformers

Rated Power (kVA)	Tier 1 (1 July 2015)	Tier 2 (1 July 2021)
	Minimum Peak Efficiency Index (%)	
$3\,150 < S_r \leq 4\,000$	99,348	99,382
5 000	99,354	99,387
6 300	99,356	99,389
8 000	99,357	99,390
$\geq 10\,000$	99,357	99,390

Minimum PEI values for kVA ratings that fall in between the ratings given in Table I.5 shall be calculated by linear interpolation.

**1.3. Requirements for medium power transformers with rated power  $\leq 3\,150$  kVA equipped with tapping connections suitable for operation while being energised or on-load for voltage adaptation purposes. Voltage Regulation Distribution Transformers are included in this category.**

The maximum allowable levels of losses set out in Tables I.1 and I.2 shall be increased by 20 % for no load losses and 5 % for load losses in Tier 1 and by 10 % for no load losses in Tier 2.

**1.4. Requirements for medium power pole-mounted transformers**

The levels of load and no load losses indicated in Tables I.1 and I.2 are not applicable to liquid immersed pole-mounted transformers with power ratings between 25 kVA and 315 kVA. For these specific models of medium power pole-mounted transformers, the maximum levels of allowable losses are set out in Table I.6.

Table I.6: Maximum load and no-load losses (in W) for medium power liquid immersed pole-mounted transformers

Rated Power (kVA)	Tier 1 (1 July 2015)		Tier 2 (1 July 2021)	
	Maximum load losses (in W) (*)	Maximum no-load losses (in W) (*)	Maximum load losses (in W) (*)	Maximum no-load losses (in W) (*)
25	$C_k$ (900)	$A_o$ (70)	$B_k$ (725)	$A_o$ (70)
50	$C_k$ (1 100)	$A_o$ (90)	$B_k$ (875)	$A_o$ (90)
100	$C_k$ (1 750)	$A_o$ (145)	$B_k$ (1 475)	$A_o$ (145)
160	$C_k + 32\%$ (3 102)	$C_o$ (300)	$C_k + 32\%$ (3 102)	$C_o - 10\%$ (270)

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Rated Power (kVA)	Tier 1 (1 July 2015)		Tier 2 (1 July 2021)	
	Maximum load losses (in W) (*)	Maximum no-load losses (in W) (*)	Maximum load losses (in W) (*)	Maximum no-load losses (in W) (*)
200	C <sub>k</sub> (2 750)	C <sub>o</sub> (356)	B <sub>k</sub> (2 333)	B <sub>o</sub> (310)
250	C <sub>k</sub> (3 250)	C <sub>o</sub> (425)	B <sub>k</sub> (2 750)	B <sub>o</sub> (360)
315	C <sub>k</sub> (3 900)	C <sub>o</sub> (520)	B <sub>k</sub> (3 250)	B <sub>o</sub> (440)

(\*) Maximum allowable losses for kVA ratings that fall in between the ratings given in Table I.6 shall be obtained by linear interpolation.

## 2. Minimum energy efficiency requirements for large power transformers

The minimum efficiency requirements for large power transformers are set out in Tables I.7 and I.8.

Table I.7: Minimum Peak Efficiency Index requirements for liquid immersed large power transformers

Rated Power (MVA)	Tier 1 (1 July 2015)	Tier 2 (1 July 2021)
	Minimum Peak Efficiency Index (%)	
≤ 4	99,465	99,532
5	99,483	99,548
6,3	99,510	99,571
8	99,535	99,593
10	99,560	99,615
12,5	99,588	99,640
16	99,615	99,663
20	99,639	99,684
25	99,657	99,700
31,5	99,671	99,712
40	99,684	99,724
50	99,696	99,734
63	99,709	99,745
80	99,723	99,758
≥ 100	99,737	99,770

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Minimum PEI values for MVA ratings that fall in between the ratings given in Table 1.7 shall be calculated by linear interpolation.

Table 1.8: Minimum Peak Efficiency Index requirements for dry-type large power transformers

Rated Power (MVA)	Tier 1 (1 July 2015)	Tier 2 (1 July 2021)
	Minimum Peak Efficiency Index (%)	
≤ 4	99,158	99,225
5	99,200	99,265
6,3	99,242	99,303
8	99,298	99,356
10	99,330	99,385
12,5	99,370	99,422
16	99,416	99,464
20	99,468	99,513
25	99,521	99,564
31,5	99,551	99,592
40	99,567	99,607
50	99,585	99,623
≥ 63	99,590	99,626

Minimum PEI values for MVA ratings that fall in between the ratings given in Table 1.8 shall be calculated by linear interpolation.

### 3. Product information requirements

From 1 July 2015, the following product information requirements for transformers included in the scope of this Regulation (Article 1) shall be included in any related product documentation, including free access websites of manufacturers:

- (a) information on rated power, load loss and no-load loss and the electrical power of any cooling system required at no load;
- (b) for medium power (where applicable) and large power transformers, the value of the Peak Efficiency Index and the power at which it occurs;

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- (c) for dual voltage transformers, the maximum rated power at the lower voltage, according to Table I.3;
- (d) information on the weight of all the main components of a power transformer (including at least the conductor, the nature of the conductor and the core material);
- (e) For medium power pole mounted transformers, a visible display 'For pole-mounted operation only'.

The information under a); c) and d) shall also be included on the rating plate of the power transformers.

**4. Technical documentation**

The following information shall be included in the technical documentation of power transformers:

- (a) manufacturer's name and address;
- (b) model identifier, the alphanumeric code to distinguish one model from other models of the same manufacturer;
- (c) the information required under point 3.

If (parts of) the technical documentation is based upon (parts of) the technical documentation of another model, the model identifier of that model shall be provided and the technical documentation shall provide the details of how the information is derived from the technical documentation of the other model, e.g. on calculations or extrapolations, including the tests undertaken by the manufacturer to verify the calculations or extrapolations undertaken.

**▼ B***ANNEX II***Measurement and calculation methods****Measurement method**

For the purpose of compliance with the requirements of this Regulation, measurements shall be made using a reliable, accurate and reproducible measurement procedure, which takes into account the generally recognised state of the art measurement methods, including methods set out in documents the reference numbers of which have been published for that purpose in the *Official Journal of the European Union*.

**Calculation methods**

The methodology for calculating the Peak Efficiency Index (PEI) for medium and large power transformers is based on the ratio of the transmitted apparent power of a transformer minus the electrical losses to the transmitted apparent power of the transformer.

$$PEI = 1 - \frac{2(P_0 + P_{c0})}{S_r \sqrt{\frac{P_0 + P_{c0}}{P_k}}}$$

Where:

$P_0$  is the no load losses measure at rated voltage and rated frequency, on the rated tap

$P_{c0}$  is the electrical power required by the cooling system for no load operation

$P_k$  is the measured load loss at rated current and rated frequency on the rated tap corrected to the reference temperature

$S_r$  is the rated power of the transformer or autotransformer on which  $P_k$  is based

**▼ M1***ANNEX III***Product compliance verification by market surveillance authorities**

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 or importer 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.

When verifying the compliance of a product model with the requirements laid down in this Regulation and its Annexes pursuant to Article 3(2) of Directive 2009/125/EC, for the requirements referred to in this Annex, the authorities of the Member States shall apply the following procedure:

- (1) The Member State authorities shall verify one single unit of the model. Given the weight and size limitations in the transportation of medium and large power transformers, Member States authorities may decide to undertake the verification procedure at the premises of manufacturers, before they are put into service in their final destination.
- (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 or importer than the results of the corresponding measurements carried out pursuant to paragraph (g) thereof; and
  - (b) the declared values meet any requirements laid down in this Regulation, and any required product information published by the manufacturer or importer does not contain values that are more favourable for the manufacturer or importer 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 given in Table 1.
- (3) If the results referred to in point 2(a), (b) or (c) are not achieved, the model shall be considered not to comply with this Regulation.
- (4) 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 being taken on the non-compliance of the model according to point 3.

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

The Member State authorities shall only apply the verification tolerances that are set out in Table 1 and shall only use the procedure described in points 1 to 4 for the requirements referred to in this Annex. No other tolerances, such as those set out in harmonised standards or in any other measurement method, shall be applied.

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*Table 1*  
**Verification tolerances**

Parameters	Verification tolerances
Load losses	The determined value shall not exceed the declared value by more than 5 %.
No-load losses	The determined value shall not exceed the declared value by more than 5 %.
The electrical power required by the cooling system for no-load operation	The determined value shall not exceed the declared value by more than 5 %.

**▼B***ANNEX IV***Indicative Benchmarks**

At the time of adoption of this Regulation, the best available technology on the market for medium power transformers was identified as follows:

- (a) Liquid-immersed medium power transformers:  $A_o - 20\%$ ,  $A_k - 20\%$
- (b) Dry-type medium power transformers:  $A_o - 20\%$ ,  $A_k - 20\%$
- (c) Medium power transformers with amorphous steel core:  $A_o - 50\%$ ,  $A_k - 50\%$

The availability of material to manufacture transformers with amorphous steel core needs further development, before such values of losses can be considered to become minimum requirements in the future.