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INTERNATIONAL STANDARD

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GROUP SAFETY PUBLICATION
PUBLICATION GROUPÉE DE SÉCURITÉ

AMENDMENT 1
AMENDEMENT 1

Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units

Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et produits analogues pour des tensions d'alimentation jusqu'à 1 100 V – Partie 2-16: Règles particulières et essais pour les blocs d'alimentation à découpage et les transformateurs pour blocs d'alimentation à découpage

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FOREWORD

This amendment has been prepared by IEC technical committee 96: Transformers, reactors, power supply units, and combinations thereof.

The text of this amendment is based on the following documents:

FDIS	Report on voting
96/401/FDIS	96/405/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION to the Amendement

This amendment has been prepared to allow the use of **FIW** wires in SMPS.

The manufacturer should be careful, that during production and transport no damage of the **FIW** wire will be possible.

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2 Normative references

Add, to the existing list of references, the following new references:

IEC 60317-0-7:2012, *Specifications for particular types of winding wires – Part 0-7: General requirements – Fully insulated (FIW) zero-defect enamelled round copper wire with nominal conductor diameter of 0,040 mm to 1,600 mm*

IEC 60317-43, *Specifications for particular types of winding wires – Part 43: Aromatic polyimide tape wrapped round copper wire, class 240*

IEC 60317-56, *Specifications for particular types of winding wires – Part 56: Solderable fully insulated (FIW) zero-defect polyurethane enamelled round copper wire with nominal conductor diameter 0,040 mm to 1,600 mm, class 180*

IEC 60851-3:2009, *Winding wires – Test methods – Part 3: Mechanical properties*

IEC 60851-5:2008, *Winding wires – Test methods – Part 5: Electrical properties*

3 Terms and definitions

Add, at the end of the existing text, the following new instruction and new terms and definitions as follows:

Addition:

3.101
FIW
fully insulated winding wire
wire according to IEC 60317-0-7, IEC 60317-56 and IEC 60851-5:2008 which is a **zero-defect wire** construction

3.102
zero-defect wire
winding wire that exhibits no electrical discontinuities when tested under specific conditions

3.103
grade of FIW
range of overall diameter of a wire (**FIW**3 – **FIW**9)

18 Insulation resistance, dielectric strength and leakage current

18.3

Add, after the existing Table 8a, the following new instruction:

Replacement of the text in footnote a of Table 8a:

[a] For construction according to 26.2.4.1, test B the voltage is multiplied by the factor 1,25. For the construction according to 26.2.4.2 the voltage is multiplied by the factor 1,35.

Add, after the existing subclause 18.101, the following new subclause and new figure:

18.102 A partial discharge test according to IEC 60664-1, (test description see below) shall be performed, if **FIW** wires are used and if the recurring peak working voltage U_t across the insulation is greater than 750 V. The relevant recurring peak voltage is the maximum measured voltage between the input and the output circuit of the SMPS, if the secondary side is earthed. The measuring shall be done at 1,0 of the maximum rated input voltage.

A partial discharge test shall be done at the transformer for the SMPS with the measured recurring peak voltage U_t, greater than 750 V peak.

U_t is the maximum peak working voltage;

t_1 is 5 s;

t_2 is 15 s.

Partial discharge shall be less than or equal to 10 pC at time t_2.

The test shall be done according to the following Figure 104.

For other applications higher values may be required (e.g. IEC 61800-5-1).

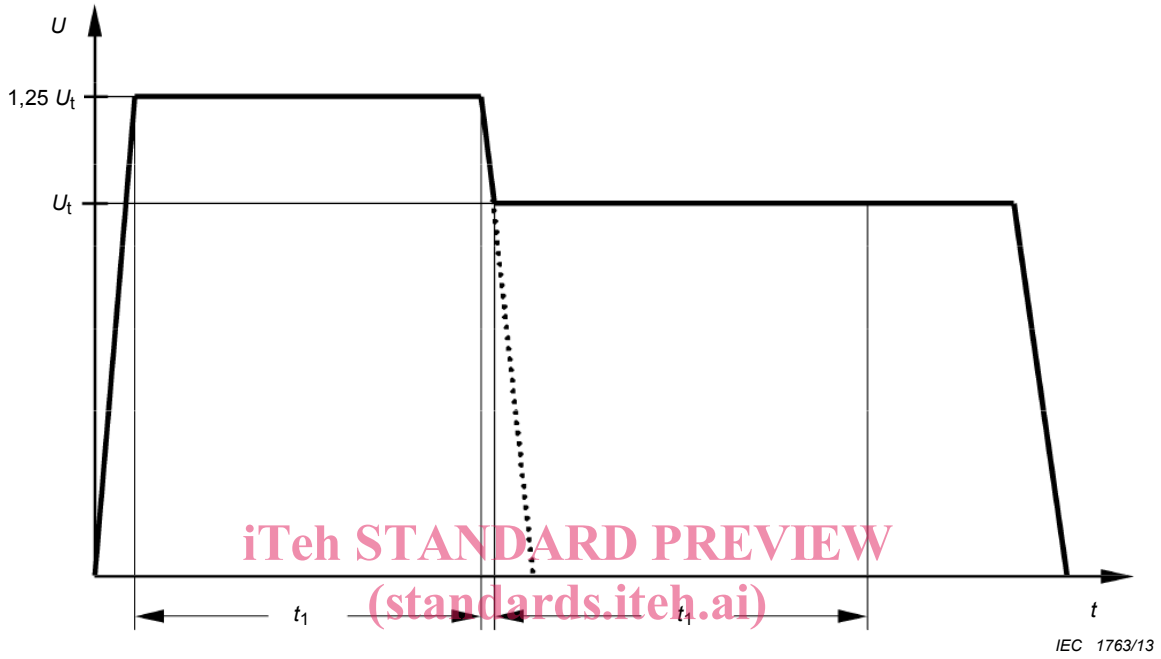

Figure 104 – Test voltages

19 Construction

Add, at the end of the existing text of this clause, the following new text:

19.12.3 *Replacement:*

Insulated winding wires, in an insulation system providing **basic, supplementary** or **reinforced insulation**, shall meet the following requirements.

Wire that has multi-layer extruded or spirally wrapped insulation (where only the finished wire can be tested) and passes the tests of Annex K.

The minimum number of constructional layers applied to the conductor shall be as follows:

– BASIC INSULATION: two wrapped layers or one extruded layer;
– SUPPLEMENTARY INSULATION: two layers, wrapped or extruded;
– REINFORCED INSULATION: three layers wrapped or extruded.

For spirally wrapped insulation where the CREEPAGE DISTANCES between layers, as wrapped, are less than those given in Clause 26. for pollution degree 1, the path between layers shall be sealed as for a cemented joint in 26.2.3, Test A and the test voltages of the TYPE TESTS in Clause K.2 are increased to 1,35 times their normal values.

NOTE 1 One layer of material wound with more than 50 % overlap is considered to constitute two layers.

The finished component shall pass ROUTINE TEST for electric strength using the appropriate value of test voltages in 18.3.

Compliance is checked by inspection and measurement and, if applicable, as specified in Annex K.

a) Where the insulation on the winding wire is used to provide **basic- or supplementary insulation** in a wound part:
   - the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
   - the insulation of one **insulated winding wire** shall consist of at least two layers for **supplementary insulation**;
   - the insulation of one **insulated winding wire** shall consist of at least one layer for **basic insulation**;
   - an insulation for mechanical separation which fulfil the electric strength test for **basic insulation** shall be provided between the **insulated wires** and the enamelled wires.

     NOTE 2 If for basic or supplementary insulation a triple insulated wire is used in combination with enamelled wire, an additional interleaved insulation (mechanical separation) is not required.

b) Where the insulation on the winding wire is used to provide **reinforced insulation** in a wound part:
   - the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
   - the insulation of one **insulated winding wire** shall consist of at least three layers;
   - the insulation is subjected to the relevant dielectric strength test of 18.3.

   Where the insulated winding wire is wound:
   - upon metal or ferrite cores or
   - upon enamelled wire or;
   - under enamelled wire;

   an insulation for mechanical separation which fulfil the electric strength test for **basic insulation** shall be provided between the insulated wires and the core or between the insulated wires and the enamelled wires. The both windings shall not touch each other and both wires shall not touch the core.

NOTE 3 This requirement takes into consideration the mechanical production stress applied to the **insulated winding wires**.

The manufacturer of the **transformer** shall demonstrate that the winding wire has been subjected to 100 % routine dielectric strength test as in Clause K.3.

No requirements for **creepage distances** and **clearances** are applicable for the **insulated winding wires**.

For windings providing **reinforced insulation**, no value is required in box 2) c) of Table 13, Table C.1 and Table D.1 of Part 1 and no values are required of 26.106.

Compliance is checked by inspection of the part and the declaration of the wire manufacturer

19.12.101 The transformer which use fully insulated winding wires (**FIW**), shall only be used up and including insulation class F.

19.12.102 Fully insulated winding wires (**FIW**) shall comply with IEC 60851-5:2008, IEC 60317-0-7 and IEC 60317-56. If the wire has other nominal diameter than in Table 111 defined, so the minimum high voltage strength value can be calculated according to formula below Table 111:

- **FIW** wires used for basic or supplementary isolation for transformers according to 19.1.2:
  - the test voltage required in Table 8a for basic/supplementary insulation according to the working voltage of the transformer, shall comply with the minimum voltage strength of basic insulation for the **FIW**-wire according to Table 111;
  - between an basic insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. The both windings shall not touch each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. Creepage distances and clearances to the **FIW** wire are not required.
- **FIW** wires used for double or reinforced insulation according to 19.1.3:
  - the test voltage required in Table 8a for basic-/supplementary insulation according to the working voltage of the transformer, shall comply with the minimum voltage strength of basic insulation for the **FIW**-wires according to Table 111. For the primary and the secondary winding a basic insulated **FIW** wire shall be used;
  - between the two basic insulated **FIW** wires an insulation for mechanical separation shall be used. The both windings shall not touch each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. Creepage distances and clearances between the **FIW** wires are not required.
- Alternative construction with **FIW**-wires reinforced insulated:
  - the test voltage required in Table 8a for reinforced insulation according to the working voltage of the transformer, shall comply with the minimum voltage strength for the **FIW** wire according to Table 111;
  - between a reinforced insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. The both windings shall not touch each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. Creepage distances and clearances to the **FIW** wire are not required.
- Alternative construction with **FIW** wires, basic or supplementary insulated for transformers with double or reinforced insulation according to 19.1.3:
  - the test voltage required in Table 8a for basic-/supplementary insulation according to the working voltage of the transformer, shall comply with the minimum voltage strength of basic insulation for the **FIW**-wire according to Table 111. For the primary or the secondary winding a basic insulated **FIW** wire shall be used. For the other winding enamelled wire can be used;
  - between the basic insulated **FIW** wire and the enamelled wire an supplementary insulation according to the working voltage is required. Creepage distances and clearances between the **FIW** wire and the enamelled wire are required for supplementary insulation.
- Where the **FIW wire** is wound:
  - upon metal or ferrite cores, an insulation for mechanical separation which fulfil the electric strength test for **basic insulation** shall be provided between the **FIW** wires and the core.The **FIW** wire and enamelled wire (if used) shall not touch the metal or ferrite core.

26 Creepage distances, clearances and distances through insulation

Add, at the end of the existing clause, the following new subclause:

26.107 For **transformers** with **FIW** wires the following test is required:

*To test the **FIW**-winding at the final **transformer**, three specimens shall be used.*

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at 25 °C ± 2 °C;

2 h at 0 °C ± 2 °C;

1 h at 25 °C ± 2 °C.

During each thermal cycling test, a voltage of twice the value of the working voltage at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens are then subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at highest temperature during the thermal cycling test.

The partial discharge test shall be done at the end of the cycling test at normal room temperature as performed in 18.101.

Table 111 – Values of FIW wires with maximum overall diameter and minimum test voltages according to the enamel increase

Calculation of test voltage for further FIW diameters : (Overall dia - copper dia) / 2 = Insulation thickness (µm)

Insulation thickness (µm) * Voltage strength per µm = minimun voltage strength for FIW design

sheet 1

Nominal FIW copper diameter	value acc. table 7 IEC 60317-0-7 :2012	Maximum overall FIW diameter including insulation							Voltage strength for basic, supplementary or reinforced insulation at FIW wire							
		FIW 3	FIW 4	FIW 5	FIW 6	FIW 7	FIW 8	FIW 9	FIW 3	FIW 4	FIW 5	FIW 6	FIW 7	FIW 8	FIW 9	
mm	V/µm	mm	mm	mm	mm	mm	mm	mm	V	V	V	V	V	V	V	
0,04	56	0,058	0,069	0,079	0,089	0,099	0,109		504	812	1092	1372	1652	1932		
0,045	56	0,066	0,078	0,089	0,100	0,111	0,122		588	924	1232	1540	1848	2156		
0,05	56	0,073	0,083	0,094	0,105	0,116	0,127		616	924	1232	1540	1848	2156		
0,056	56	0,081	0,092	0,104	0,116	0,128	0,140		700	1008	1344	1680	2016	2352		
0,063	56	0,090	0,102	0,115	0,128	0,141	0,154		756	1092	1456	1820	2184	2548		
0,071	56	0,098	0,110	0,123	0,136	0,149	0,162	0,175	756	1092	1456	1820	2184	2548	2912	
0,08	56	0,108	0,122	0,136	0,150	0,164	0,178	0,192	784	1176	1568	1960	2352	2744	3136	
0,09	56	0,120	0,134	0,148	0,162	0,176	0,190	0,204	840	1232	1624	2016	2408	2800	3192	
0,1	56	0,132	0,148	0,164	0,180	0,196	0,212	0,228	896	1344	1792	2240	2688	3136	3584	
0,112	53	0,147	0,164	0,181	0,198	0,215	0,232	0,249	928	1378	1829	2279	2730	3180	3631	
0,125	53	0,163	0,181	0,199	0,217	0,235	0,253	0,271	1007	1484	1961	2438	2915	3392	3869	
0,14	53	0,181	0,201	0,221	0,241	0,261	0,281	0,301	1087	1617	2147	2677	3207	3737	4267	
0,16	53	0,205	0,227	0,249	0,271	0,293	0,315	0,337	1193	1776	2359	2942	3525	4108	4691	
0,18	53	0,229	0,253	0,277	0,301	0,325	0,349	0,373	1299	1935	2571	3207	3843	4479	5115	
0,2	53	0,252	0,277	0,302	0,327	0,352	0,377	0,402	1378	2041	2703	3366	4028	4691	5353	
0,224	53	0,280	0,307	0,334	0,361	0,388	0,415	0,442	1484	2200	2915	3631	4346	5062	5777	
0,25	53	0,312	0,342	0,372	0,402	0,432	0,462	0,492	1643	2438	3233	4028	4823	5618	6413	
0,28	53	0,345	0,376	0,407	0,438	0,469	0,500	0,531	1723	2544	3366	4187	5009	5830	6652	
0,315	53	0,384	0,415	0,446	0,477	0,508	0,539	0,570	1829	2650	3472	4293	5115	5936	6758	
0,355	49	0,428	0,459	0,490	0,521	0,552	0,583	0,614	1789	2548	3308	4067	4827	5586	6346	
0,4	49	0,478	0,509	0,540	0,571	0,602	0,633		1911	2671	3430	4190	4949	5709		
0,45	49	0,533	0,564	0,595	0,626	0,657	0,688		2034	2793	3553	4312	5072			
0,5	49	0,587	0,628	0,669	0,710	0,751			2132	3136	4141	5145	6150			
0,56	37	0,653	0,694	0,753	0,776	0,817			1721	2479	3571	3996	4755			
0,63	37	0,728	0,769	0,810	0,851	0,892			1813	2572	3330	4089	4847			
0,71	37	0,814	0,855	0,896	0,937	0,978			1924	2683	3441	4200	4958			
0,8	37	0,911	0,962	1,013	1,064				2054	2997	3941	4884				
0,9	37	1,018	1,069	1,120	1,171				2183	3127	4070	5014				
1	37	1,124	1,175	1,226	1,277				2294	3238	4181	5125				
1,12	33	1,248	1,309	1,370					2112	3119	4125					
1,25	33	1,381	1,442	1,503					2162	3168	4175					
1,4	33	1,535	1,596	1,657					2228	3234	4241					
1,6	33	1,740	1,801	1,862					2310	3317	4323					

The values of allowed voltage strength for other **FIW** dimensions than defined in Table 111 are calculated according following formula:

$$V = \frac{d_a - d_{cu}}{2} \times U \times 10^3$$

where

d_a is the maximum overall diameter in (mm);

d_{cu} is the nominal copper diameter in (mm);

U is the voltage value according to Table 7 of IEC 60317-0-7 (see column 2) in (V/μm);

V is the allowed voltage strength for **FIW** wire in (V).

Higher voltage values, based on the "enamel increase" of Table 7 of IEC 60317-0-7:2012, are under consideration.

Annexes

Add, before the existing word "Addition", the following new text and new annex as follows:

Replacement of Annex K:

Annex K
(normative)

Insulated winding wires

K.1 General

This annex specifies the winding wires of the insulation that may be used to provide **basic insulation**, **supplementary insulation**, **double insulation** or **reinforced insulation** in wound components. For details of the construction, see 19.12.3.

This annex applies to solid circular winding wires and stranded winding wires having diameters between 0,05 mm and 5,0 mm and solid square and solid rectangular (flatwise bending) winding wires with equivalent cross-sectional areas (0,002 to 19,6 mm^2).

If the wire is insulated with two or more spirally wrapped layers of tape, the overlap of layers shall be adequate to ensure continued overlap during manufacture of the wound component. The layers of spirally wrapped wire insulation shall be sufficiently secured to maintain the amount of overlap.

K.2 Type tests

K.2.1 General

*The winding wire shall pass the following **type tests**, carried out at a temperature between 15 °C and 35 °C and a relative humidity between 25 % and 75 %, unless otherwise specified.*

K.2.2 Electric strength

K.2.2.1 Solid circular winding wires and stranded winding wires

The test sample is prepared according to 4.4.1 of IEC 60851-5:2008 (twisted pair). The sample is then subjected to the electric strength test of 18.3 in this standard with a test voltage standard, with a minimum of:

– *6 kV r.ms. for **reinforced insulation**, or*

– *3 kV r.m.s. for **basic insulation** or **supplementary insulation**.*

K.2.2.2 Square or rectangular wires

The test sample is prepared according to 4.7.1 of IEC 60851-5:2008 (single conductor surrounded by metal shots). The sample is then subjected to the electric strength test of 18.3 of this standard, with a minimum test voltage of:

– *5,5 kV r.m.s. for **reinforced insulation**, or*

– *2,75 kV r.m.s. for **basic insulation** or **supplementary insulation**.*

K.2.3 Flexibility and adherence

5.1 (in Test 8) of IEC 60851-3:2009 shall be used, using the mandrel diameters of Table K.1. The test voltage is applied between the wire and the mandrel.

The test sample is then examined in accordance with 5.1.1.4 of IEC 60851-3:2009, followed by the electric strength test of 18.3 in this standard, with minimum test voltage of:

– *5,5 kV r.m.s. for **reinforced insulation**, or*