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| --- | --- |
| **Document Type** | Material Specification |
| **Scope of Activity** | Transformer Insulation |

**Transformer Insulation**

Solid insulation within the windings and clamping structure shall be of a suitable cellulosic material supplied by a manufacturer with a proven history (15 or more year experience, supported by technical development and testing) and shall comply with current applicable industry standards for dielectric integrity, short circuit, thermal requirements, loss of life, and emergency loading.

As a general rule, Insulation for a single transformer should all be sourced from a single supplier in order to ensure that the performance of the product e.g. shrinkage and compressibility is uniform throughout the transformer.

Specification according to IEC 60641 and IEC 60763

**Precompressed - High Density - Transformer Board**

Standard IEC 60641-1 Type B5.1

IEC Class A, 105 ºC

Colour Natural brown

Apparent density [g/cm³]

< 1,6 mm 1,00 - 1,20

> 1,6 - 3,0 mm 1,10 - 1,25

> 3,0 mm 1,15 - 1,30

Tensile strength MD [N/mm²]

< 1,6 mm Min 100,0

> 1,6 - 3,0 mm Min 105,0

> 3,0 mm Min 110,0

Tensile strength CMD [N/mm²]

< 1,6 mm Min 75,0

> 1,6 - 3,0 mm Min 80,0

> 3,0 mm Min 85,0

Elongation at fracture [%]

MD Min 2,5

CMD Min 3,5

Compressibility C [%]

< 1,6 mm Max 10,0

> 1,6 - 3,0 mm Max 7,5

> 3,0 - 6,0 mm Max 5,0

> 6,0 mm Max 4,5

Compressibility reversible Crev [%]

< 1,6 mm Min 45,0

> 1,6 - 8,0 mm Min 50,0

Shrinkage [%]

MD Max 0,5

CMD Max 0,7

Thickness Max 6,0

Plybond resistance [N/30 mm] Min 250

Moisture content at delivery [%] Max 6,0

Ash content [%] Max 0,7

Conductivity of aqueous extract [mS/m]

< 1,6 mm Max 5,0

> 1,6 - 3,0 mm Max 6,0

> 3,0 - 6,0 mm Max 8,0

> 6,0 mm Max 10,0

pH of aqueous extract [pH] 6,0 - 9,0

Oil absorption [%]

< 1,6 mm Min 11,0

> 1,6 - 3,0 mm Min 9,0

> 3,0 - 6,0 mm Min 7,0

> 6,0 mm Min 6,0

Electric strength in oil [kV/mm]

< 1,6 mm Min 45,0

> 1,6 mm Min 35,0

Dissipation factor tan delta at 105°C 0,004

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| **Transformer Board** | | | | | |
| **Standard sizes** | | | | | |
| **Thickness** | **Tolerance** | **Length (MD)** | **Width** | **Material** | **Material Manufacturer** |
| 0.8 mm |  | 4200 mm | 3200 mm | Elboard HD | Figeholm |
| 1 mm |  | 4200 mm | 1600 mm |
| 1.5 mm |  | 4200 mm | 1050 mm |
| 2 mm |  | 2100 mm | 3200 mm |
| 3 mm |  | 2100 mm | 1600 mm |
| 4 mm |  | 2100 mm | 1050 mm |
| 5 mm |  | 1400 mm | 3200 mm |
| 6 mm |  | 700 mm | 1050 mm |
| 7 mm |  |  |  |
| 8 mm |  |  |  |
| 1 mm | ± 7.5% | 6300 mm | 3200 mm | T IV | Weidmann |
| 1.5 mm | ± 7.5% | 6300 mm | 1600 mm |
| 2 mm | ± 5.0% | 4200 mm | 3200 mm |
| 2.5 mm | ± 5.0% | 4200 mm | 1600 mm |
| 3 mm | ± 5.0% | 3150 mm | 3200 mm |
| 4 mm | ± 5.0% | 3150 mm | 1600 mm |
| 5 mm | ± 5.0% | 2100 mm | 3200 mm |
| 6 mm | ± 5.0% | 2100 mm | 1600 mm |
| 7 mm | ± 5.0% | 2100 mm | 1065 mm |
| 8 mm | ± 5.0% |  |  |

**High Density Polyester Laminated Transformer Board**

Standard IEC 60763 Type LB.3.1 A.2

IEC Class A, 105 ºC

Colour Natural brown

Thickness deviation from nominal [%]

6 - 12 mm ±5,0

> 12 mm ±4,0

Flexural strength [N/mm²]

MD Min 110,0

CMD Min 90,0

Compressibility C [%]

Max 3,0

Compressibility reversible Crev [%]

Min 70,0

Electric strength in oil - Parallel to layers [kV/mm]

Min 8,0

Apparent density [g/cm³]

1,15 - 1,35

Moisture content at delivery [%]

Max 5,0

Shrinkage [%]

MD Max 0,4

CMD Max 0,6

Thickness Max 4,0

Oil absorption [%]

Min 5,0

Ash content [%]

TBA

Conductivity of aqueous extract [mS/m]

Max 10,0

pH of aqueous extract [pH]

5,0 - 8,0

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| **High Density Polyester Laminated Transformer Board** | | | | | |
| **Standard Sizes** | | | | | |
| **Thickness** | **Tolerance** | **Length** | **Width** | **Material** | **Material Manufacturer** |
| ≤12 | ± 5.0% | 4100 mm | 3100 mm | HDLP | Figeholm |
| 13 – 200 mm | ± 4.0% | 4100 mm | 1550 mm |
|  |  | 4100 mm | 1030 mm |
|  |  | 2050 mm | 3100 mm |
|  |  | 2050 mm | 1550 mm |
|  |  | 2050 mm | 1030 mm |
| ≤12 | ± 5.0% | 4000 mm | 1500 mm | Laminated TIV 2 | Weidmann |
| 13 – 200 mm | ± 4.0% | 4000 mm | 750 mm |
|  |  | 4000 mm | 500 mm |
|  |  | 2000 mm | 1500 mm |
|  |  | 2000 mm | 750 mm |
|  |  | 1000 mm | 1500 mm |
|  |  | 1000 mm | 750 mm |
|  |  | 3000 mm | 2000 mm |
|  |  | 1500 mm | 2000 mm |
|  |  | 1000 mm | 2000 mm |

**High Density Casein Laminated Transformer Board**

Standard IEC 60763 Type LB.3.1 A.1

IEC Class A, 105 ºC

Colour- Natural brown

Flexuralstrength[N/mm2]

MD Min 100,0

CMD Min 80,0

Compressibility C [%]

Max 3,5

Compressibility reversible Crev [%]

Min 65,0

Electric strength in oil-­‐Parallel to layers [kV/mm]

Min 8,0

Apparent density[g/cm3]

1,15 - 1,30

Moisture content at delivery [%]

Max 8,0

Shrinkage[%]

MD Max 0,5

CMD Max 0,7

Thickness Max 6,0

Oil absorption [%]

Min 6,0

Ash content [%]

TBA

Conductivity of aqueous extract [mS/m]

Max 15,0

pH of aqueous extract [pH]

6,0 - 10,0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **High Density Casein Laminated Transformer Board** | | | | | |
| **Standard Sizes** | | | | | |
| **Thickness** | **Tolerance** | **Length** | **Width** | **Material** | **Material Manufacturer** |
| ≤12 | ± 5.0% | 4100 mm | 3100 mm | HDLP | Figeholm |
| 13 – 200 mm | ± 4.0% | 4100 mm | 1550 mm |
|  |  | 4100 mm | 1030 mm |
|  |  | 2050 mm | 3100 mm |
|  |  | 2050 mm | 1550 mm |
|  |  | 2050 mm | 1030 mm |
| ≤12 | ± 5.0% | 4000 mm | 1500 mm | Laminated TIV 2 | Weidmann |
| 13 – 200 mm | ± 4.0% | 4000 mm | 750 mm |
|  |  | 4000 mm | 500 mm |
|  |  | 2000 mm | 1500 mm |
|  |  | 2000 mm | 750 mm |
|  |  | 1000 mm | 1500mm |
|  |  | 1000 mm | 750 mm |
|  |  | 3000 mm | 2000 mm |
|  |  | 1500 mm | 2000 mm |
|  |  | 1000 mm | 2000 mm |

**Structural Components**

Standard: IEC 60641-1

IEC Class A, 105 ºC

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Standard Sizes** | | | | **Material** | **Material Manufacturer** |
|  | **Thickness** | **Height** | **Width** | **Length** |  |  |
| Angle Boad/L-Profile | 6 mm | 60 mm | 60 mm | 4 m | Elboard HD | Figeholm |
| 8 mm | 80 mm | 80 mm | 4 m |
| 9 mm | 80 mm | 80 mm | 4 m |
| 9 mm | 100 mm | 100 mm | 4 m |
| 12 mm | 100 mm | 100 mm | 4 m |
| 14 mm | 120 mm | 120 mm | 4 m |
| 14 mm | 140 mm | 125 mm | 4 m |
| 10 mm | 100-150 mm | 100-150 mm | 3 m | TIV | Weidmann |
| Transformer Board Rings | There are no standard sizes; it depends on the transformer design. | | | | Elboard HD | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | TIV | Weidmann |
| End Support Blocks | There are no standard sizes; it depends on the transformer design. | | | | HDLC | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | Laminated TIV 1 | Weidmann |
| Press Frames/Rings | There are no standard sizes; it depends on the transformer design. | | | | HDLP/HDLC | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | Laminated TIV 2/1 | Weidmann |
| Step Blocks | There are no standard sizes; it depends on the transformer design. | | | | HDLP/HDLC | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | Laminated TIV 2/1 | Weidmann |
| Ribs/Slats | There are no standard sizes; it depends on the transformer design. | | | | Elboard HD/HDLC | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | TIV/Laminated TIV 1 | Weidmann |
| Filler Wedges | There are no standard sizes; it depends on the transformer design. | | | | Elboard HD/HDLC | Figeholm |
| There are no standard sizes; it depends on the transformer design. | | | | TIV/Laminated TIV 1 | Weidmann |

|  |  |  |  |
| --- | --- | --- | --- |
| Wrappers | There are no standard sizes; it depends on the transformer design. | Elboard HD | Figeholm |
| There are no standard sizes; it depends on the transformer design. | TIV | Weidmann |
| Harness Support Structure | There are no standard sizes; it depends on the transformer design. | HDLC/HDLP | Figeholm |
| There are no standard sizes; it depends on the transformer design. | Laminated TIV 2/1 | Weidmann |

**Winding Insulation**

Standard: IEC 60641-1

IEC Class A, 105 ºC

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **Standard Sizes** | | | **Material** | **Material Manufacturer** |
|  | **Thickness** | **Width** | **Length** |  |  |
| Clack Strips | 1 mm | 20 mm  27 mm  30 mm  38 mm  50 mm  60 mm | 2000 mm  3000 mm  4000 mm | Calibrated strip Elboard HD | Figeholm |
| 1.5 mm |
| 2 mm |
| 3 mm |
|  |
|  |
| 1 mm | 38 mm  50 mm  60 mm | 2070 mm | Calibrated Strip TIV | Weidmann |
| 1.5 mm |
| 2 mm |
| 3 mm |
| Snouts/moulded products | According to design | | | Elboard LD | Figeholm |
| According to design | | | TIII | Weidmann |
| Stress shield cyllinders | According to design | | | Elboard HD | Figeholm |
| According to design | | | TIV | Weidmann |
| Stress shield rings | According to design | | | Elboard HD/HDLC | Figeholm |
| According to design | | | TIV/Laminated TIV 1 | Weidmann |
| Helical end rings | According to design | | | Elboard HD/HDLC | Figeholm |
| According to design | | | TIV/Laminated TIV 1 | **Weidmann** |
| Crossover protectors | 0.5 mm | Varied | Varied | Elboard HD/PressPan | Figeholm/Pucaro |
| 1 mm | Varied | Varied |
| 0.5 mm | Varied | Varied | TI/TIV | Weidmann |
| 1 mm | Varied | Varied |
| Clack Band | According to design | | | Presspaper and Elboard HD | Figeholm |
| According to design | | | Presspaper and TIV | Weidmann |
| Threaded Durastone rod | M8 |  | 2 m |  |  |
| M12 |  |  |  |
| M16 |  |  |  |
| Durastone nuts and bolts | M8 |  |  |  |  |
| M12 |  |  |  |
| M16 |  |  |  |

**Winding Cylinders**

Winding cylinders shall preferably be delivered closed (glued) and pre-stabilised with transformer oil.

IEC Class A, 105 ºC

Glueing

Cylinders shall only be glued with high quality casein glue or Kaskarite.

Other manufacturer recommended urea–formaldehyde resin glues may also be submitted for approval.

Scarfing/Chamfering

All joints shall be chamfered according to the following:

|  |  |  |  |
| --- | --- | --- | --- |
| **Glued Joints** | | **Non glued joints** | |
| **Material thickness** | **Minimum Chamfer** | **Material thickness** | **Minimum Chamfer** |
| 2 mm | 60 mm | 2 mm | 100 mm |
| 3 mm | 90 mm | 3 mm | 150 mm |
| 4 mm | 120 mm | 4 mm | 200 mm |
| 5 mm | 150 mm | 5 mm | 250 mm |

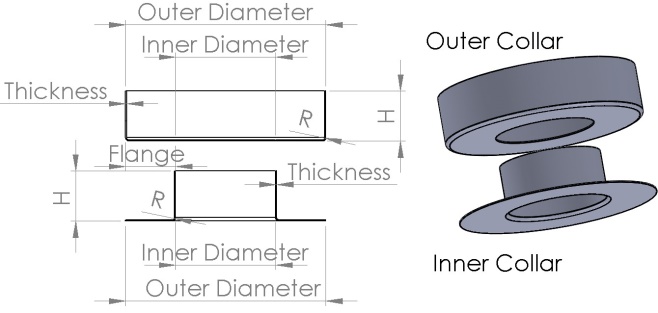
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Standard Sizes** | | | | | **Material** | **Material Manufacturer** |
| **Thickness** | **Inner Dia.** | **Height** | **Tolerance on I.D.** | **Chamfer** |  |  |
| 2 mm | Varied | Varied | 1 mm | 60 mm | Elboard HD | Figeholm |
| 3 mm | Varied | Varied | 1 mm | 90 mm |
| 4 mm | Varied | Varied | 1.5 mm | 120 mm |
| 5 mm | Varied | Varied | 1.5 mm | 150 mm |
| 2 mm | Varied | Varied | 1 mm | 60 mm | TIV | Weidmann |
| 3 mm | Varied | Varied | 1 mm | 90 mm |
| 4 mm | Varied | Varied | 1.5 mm | 120 mm |
| 5 mm | Varied | Varied | 1.5 mm | 150 mm |

**Inner and outer collars/angle rings**

Standard: IEC 60641-1

IEC Class A, 105 ºC

Standard Profile



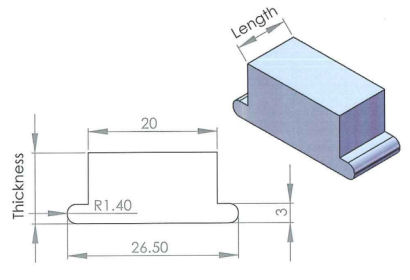
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Standard Sizes** | | | | | **Material** | **Material Manufacturer** |
|  | **Thickness** | **I.D.** | **Flange** | **Height** | **Radius** |  |  |
| Inner and outer collars/angle rings | 2 mm  3 mm  4 mm  5 mm | < 650 mm | ≤80 mm | ≤110 mm | 5 mm  15 mm  25 mm | Elboard LD | Figeholm |
| 650-1200 mm | ≤80 mm | ≤150 mm |
| >1200 mm | ≤100 mm | ≤180 mm |
| 2 mm  3 mm  4 mm | 250-370 mm | ≤110 mm | ≤110 mm | ≤ 24 mm | TIII | Weidmann |
| 371-660 mm | ≤135 mm | ≤130 mm |
| 661-1280 mm | ≤220 mm | ≤170 mm |
| 1281-2110 mm | ≤230 mm | ≤190 mm |
| Inner and outer edge protectors | 0.5mm | varied | varied | varied | 2 mm |  | Figeholm |
| 1 mm | varied | varied | varied |
| 0.5 mm | varied | varied | varied | 2 mm |  | Weidmann |
| 1 mm | varied | varied | varied |

**T – Sticks**

Standard: IEC 60641-1

IEC Class A, 105 ºC

Standard Profile



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Standard Sizes** | | **Material** | **Material Manufacturer** |
|  | **Thickness** | **Length** |  |  |
| T-Stick | 8 mm | ≤3000 mm | HDLC | Figeholm |
| 11mm | ≤3000 mm |
| 8 mm | ≤3000 mm | Laminated TIV 1 | Weidmann |
| 11 mm | ≤3000 mm |

**Tapes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Standard Sizes** | | | | **Material** | **Material Manufacturer** |
|  | **Thickness** | **Width** | **Elongation** | **Thermal class** |  |  |
| Crepe tape (Kraft) |  | 20 - 40 mm |  | A, 105ºC |  |  |
| Crepe tape (thermally upgraded kraft) |  | 20 - 40 mm |  | E, 120ºC |  |  |
| Strong tape/fibre re-inforced kraft paper tape |  | 10 -20 mm |  | A, 105ºC |  |  |
| Thermo- setting Resin impregnated Fibre-glass tape |  | 20 – 50 mm |  | H, 200 ºC |  |  |
| Enamel tape |  |  |  |  |  |  |
| Foil Tape |  |  |  | A, 105ºC |  |  |
| Cotton tape |  | 20 - 40 mm |  | A, 105ºC |  |  |