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on

"Current & Futuristic Prospects of Transformer Technology on Global Horizon and Challenges for Indian Power Sector"

Organized by

Indian Transformer Manufacturers Association (ITMA)

Jointly With

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PFCL — Power Finance Corporation Ltd.

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ERDA — Electrical Research and Development Association

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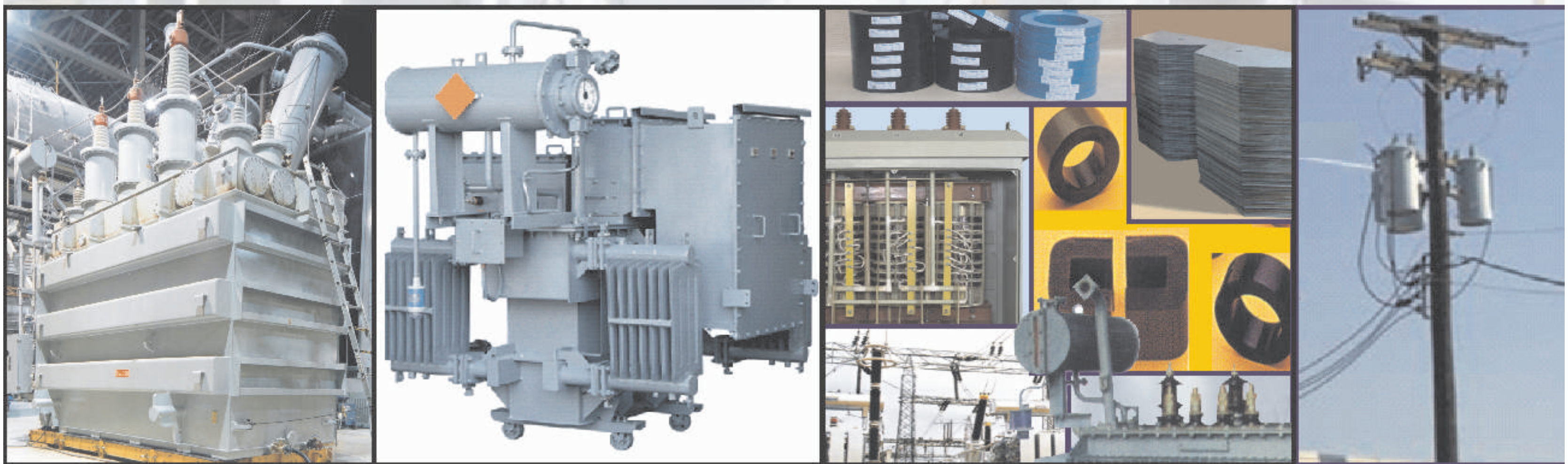

on

21st & 22nd November 2011

at

STEIN AUDITORIUM

Convention Centre, India Habitat Centre, Gate No 3, Lodhi Road, New Delhi–110003

MODERN TRENDS IN APPLICATION OF INSULATION SYSTEMS FOR POWER TRANSFORMERS

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Abstract

The solid insulation components have a considerable effect in order to reduce the cost of Transformers. An optimized design of the insulation system can make possible to reduce the weight and overall size of transformers, without compromising the quality. That means smaller active parts, smaller tanks, less oil and smaller Magnetic Core.

Keywords; Insulation Components, Insulation Design, Solid Insulation, Barrier System, Lead Exits, Dielectric Stress

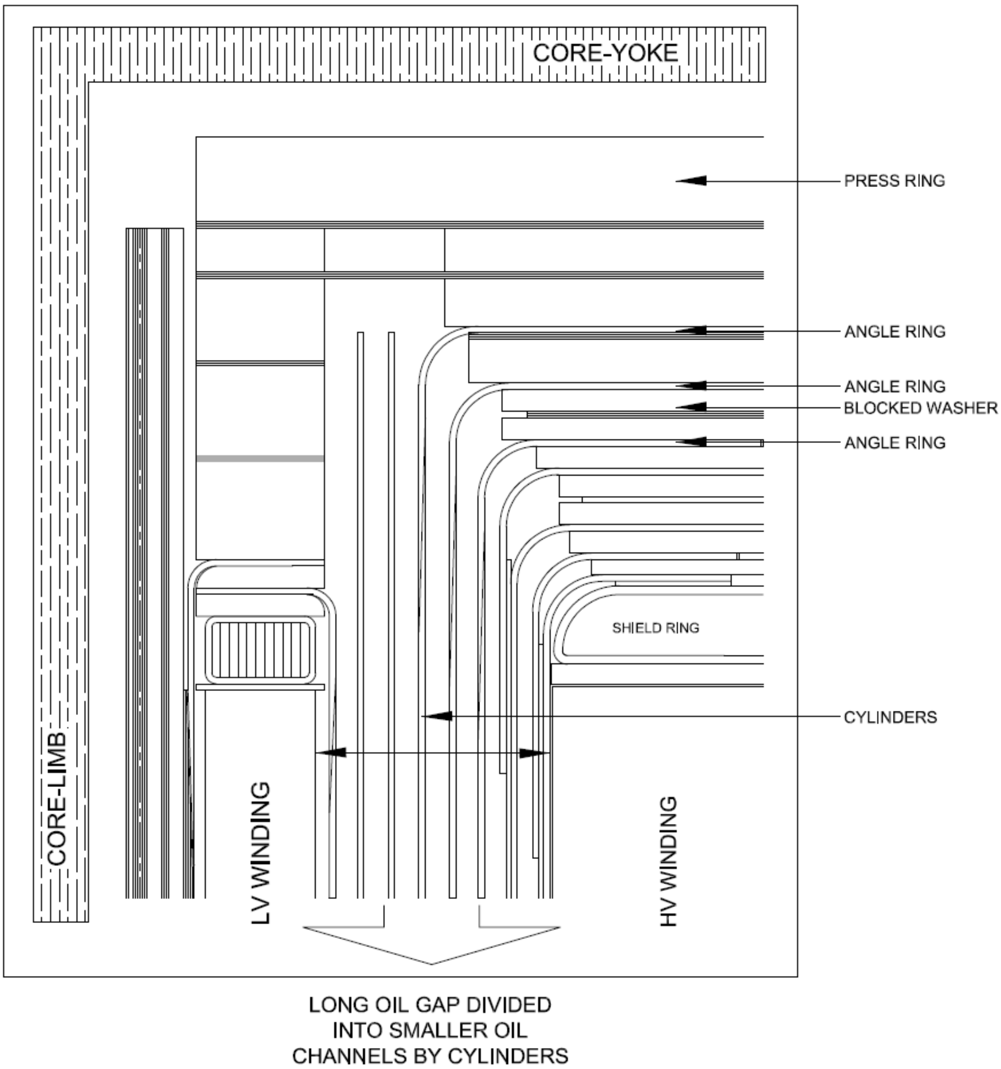
Introduction

The competition of the HV Power Transformer producers is getting harder and harder. One of the most important challenges to reduce the cost of Transformers is the optimization of Insulation Components and systems. Successful Performance can be achieved by well established design criteria and by high quality manufacturing of Insulation Components. The main topic of design criteria is general function of liquid and solid insulations. As liquids are different types of transformer oils, dielectric strength of oil is less than Transformerboard material which is made of cellulose based Insulation Board. But solid insulations get their electrical strength only by impregnation with oil. The dielectric properties depend on a number of parameters. We will focus on components.

Application of Pressboard in Power Transformer

In insulation design, field stress distribution between oil impregnated solid insulations is taken as the fundamental criteria. In AC transformers this stress is distributed in accordance with the permittivity of insulating materials and the geometry; however in DC transformers these criterions are different. Furthermore the insulation arrangement is constituted according to the design curves. They are based on decades of experience and depend upon manufacturing, process, workmanship and quality of materials as well as others.

The crucial usage of board in transformers is subdivision of the wide oil gaps into smaller oil gaps. Transformerboard has pure cellulose fibres that increase the oil strength and provide a higher safety margin. [10], [11]

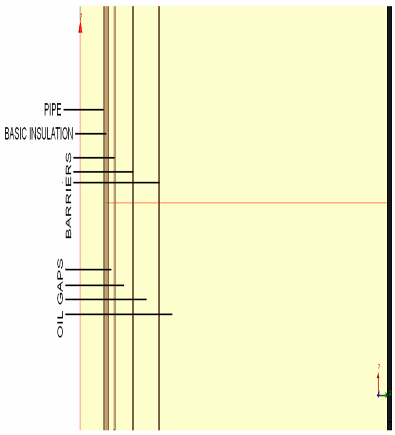


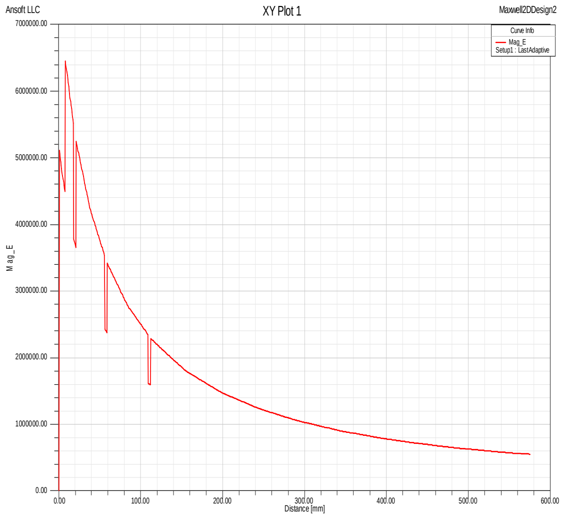
Schematical barrier system at the upper end of the transformer windings.

Barrier Systems

As far as the term of ‘barriers’ is concerned, barriers are designed to stop discharge that is spreading. Therefore, barriers can also be regarded as against widespread propagation of the discharge channel.

Barrier system in power transformers

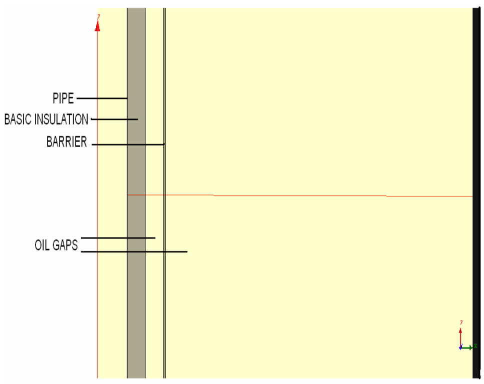


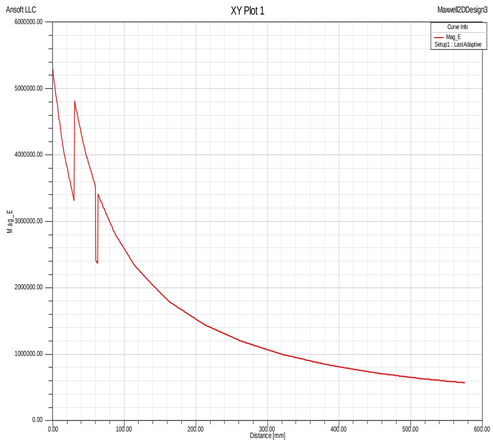


Electrostatic field through the red line that can be shown at left model.

- In barriers systems HV potential wound with relatively thin basic insulation with barriers that is designed according to PD inception design curves with advanced Electrostatic analysis programs.
- These are safer designs because large statistical scatter of the discharge occurrence will be reduced to the value of the scatter for limited gaps and scatter of complete system is smaller.
- This system provide less drying and impregnation time due to the more thin insulation layer.
- Less mineral oil, steel usage

Conventional insulation system in power transformers





Electrostatic field through the red line that can be shown at left model.

- In conventional systems HV potential wound with relatively thick basic insulation with no barrier or small amount of barrier in accordance with stress level.
- Due to the thick basic insulation that is wound over the HV potential drying and impregnation time is long.
- Less safe design because large statistical scatter of the discharge occurrence no reduced with narrower gaps and scatter of complete system is no small.

As it is shown on the above illustration the dielectric strength of wide oil gaps can be enhanced by dividing into shorter distances. Transformer manufacturers can attain smaller volume of insulation structure with this way. If the gaps are subdivided, large statistical scatter of the discharge occurrence will be reduced to the value of the scatter for limited gaps. Because of this, scatter of complete system is smaller. In non-uniform field, oil gap can be divided into shorter spaces of different lengths. In order to determine this lengths designers have to use electrostatic analyze programs and special design curves. At the same time the barriers must guarantee mechanical stability of system.

Moreover, other important characteristic of the barrier systems is that they are suitable for drying process. In case of thick insulation usage, the drying process takes longer time than thin board. As shown in below table you can compare the duration of drying time of different board thickness in the ventilated oven at 105˚C ± 5K. (In case of vapor phase drying the time is much shorter)

Nominal Thickness s (mm)	$\leq 0{,}5$	$0{,}5 < s \leq 1{,}5$	$1{,}5 < s \leq 5{,}0$	> 5
Time (h) (minimum)	12	24	48	72

This value is defined in IEC 60641-2

Therefore, the barrier system is more convenient. We can decrease the probability of fault by means of less drying process duration.

Aforementioned that wide oil gaps are divided into smaller oil gaps by barriers. Another mission of the oil channel is suspending heat and decreasing temperature easily. Thus we can reduce probability of fault that depends on thermal fact.

Lead Exits

The lead exit is a special insulation component that is used to provide safety connection of high voltage winding end and bushing bottom and at the same time it makes cost optimization of steel and oil.[7] , [8]. The turret diameter or the distance to transformer tank depends on system voltage and design of the lead exit. Lead exit allows reducing the diameter of turret or distance to transformer tank due to construction of barriers therefore provides saving materials for power transformer manufacturers. When we analyze the total cost of steel and oil, which are used at turret or transformer tank, big reduction can be observed.

Old conventional system of lead exits with paper wrapped conductor and single wide oil gap has a big disadvantage. These are much costlier and inefficient technical solutions compared with state- of -the art barrier systems.

Lead Exits are produced in different type (located inside tank or inside turret) and different voltage level up to 1200 kV

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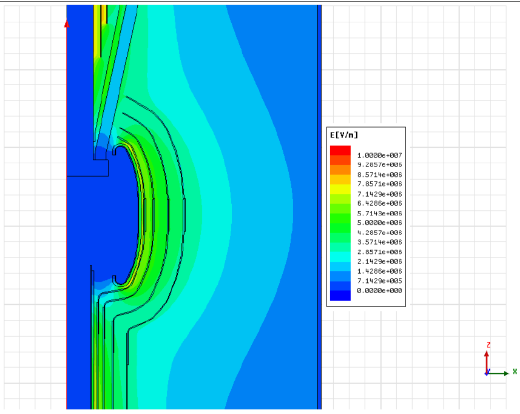
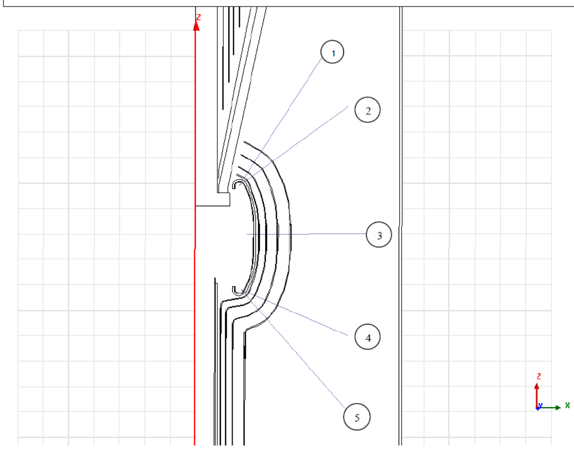
Lead Exit Design

1200 kV BIL: 2300 kV SIL : 1800 kV

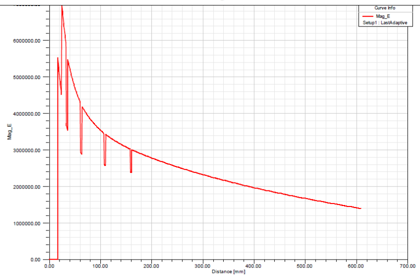
Equipotential lines of 1200 kV LEAD EXIT



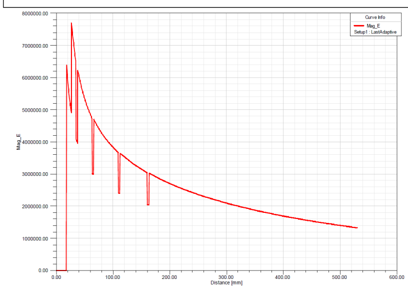
1200 kV Lead Exit Electrostatic Analyze of Electrode versus Turret



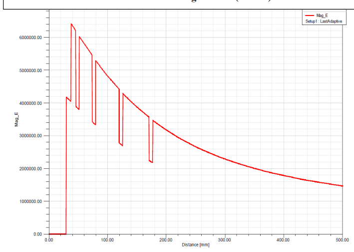
2D Electrostatic Field Analyze of 1200 kV LEAD EXIT - Curve that belong to line 1 (V / m)



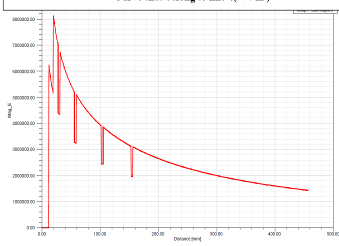
Electrostatic Field Analyze of 1200 kV LEAD EXIT - Curve that belong to line 2(V / m)



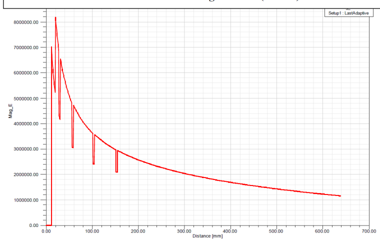
Electrostatic Field Analyze of 1200 kV LEAD EXIT - Curve that belong to line 3(V / m)



Electrostatic Field Analyze of 1200 kV LEAD EXIT - Curve that belong to line 4(V / m)



Electrostatic Field Analyze of 1200 kV LEAD EXIT - Curve that belong to line 5 (V / m)



Curves that belong to line 1-5 (V/m)

Lead EXİTS produced by ENPAY

Um : 420 kV
BIL : 1300 kV
SIL : 900 kV

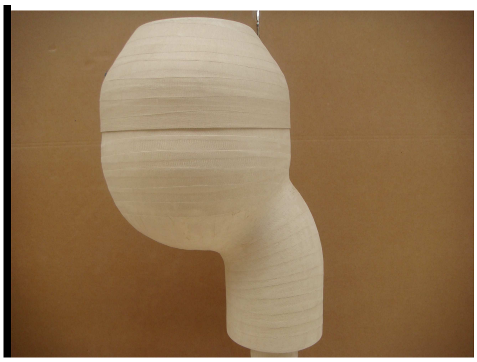
Um : 550 kV
BIL : 1175 kV
SIL : 1425 kV

Um : 1200 kV
BIL : 2300 kV
SIL : 1800 kV

Um : 1200 kV
BIL : 2300 kV
SIL : 1800 kV

Um : 800 kV
BIL : 1950 kV
SIL : 1550 kV

Um : 550 kV
BIL : 1175 kV
SIL : 1425 kV



Um : 550 kV
BIL : 1175 kV
SIL : 1425 kV

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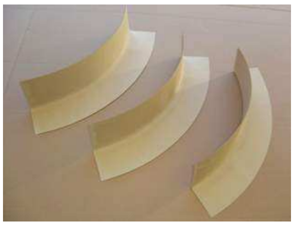
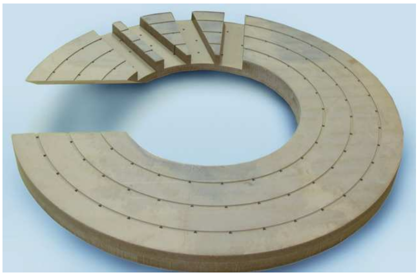
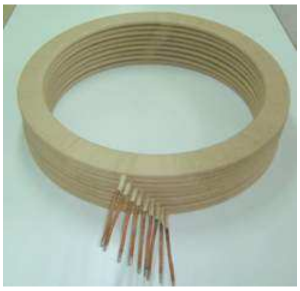
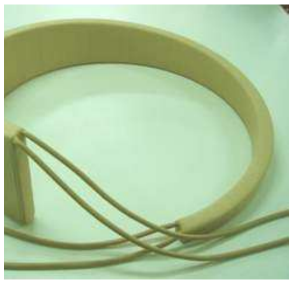
Some of Insulation Component Parts






Winding Kits/ Winding Packages
Kits allows for less production costs and decrease manufacturing cycle time of power transformer production. No need to store the cylinders, strips, spacers, separately etc.

Press Rings / Clamping Rings
The rings are made of Laminated Pressboard according to IEC 60763.Thicknesses up to 150 mm. Glue material is polyester.

Shield Rings / Shield End Rings

Fundamental Differences Between Oil Impregnated Pressboard-Laminated Board and Resinbonded Papers-Laminated Wood

a. Comparison of Pressboard with Resin Bonded Papers and Tubes (Cylinders)
Following standards are giving general information;

IEC 60641 – Pressboard - IEC 60641-3-1 TYPE B.3.1 A

IEC 60893-3-4 TYPE PF CP 202 – DIN 7735 HP 2061.5 – Resin Bonded Laminated Sheets

IEC 61212-3-1 TYPE PF CP 21 – TYPE PF CP 22 – Round Laminated Rolled Tube

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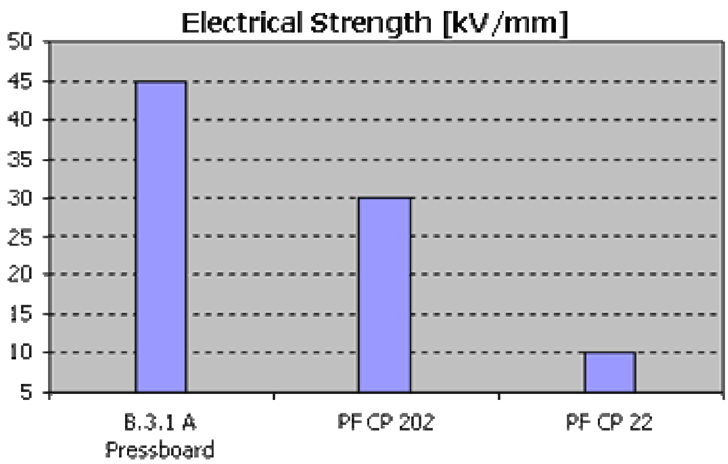
Comparison Table

Definition	Standard	Thermal Class [°C]	Density [g/cm^3] {*}	Electrical Strength [kV/mm]
Pressboard TYPE **B.3.1 A**	IEC 60641	A-105	1,10 – 1,30	45{**}
Resin Bonded Laminated Sheets TYPE **PF CP 202**	IEC 60893	E-120	1,30 – 1,40	30{**}
Round Laminated Rolled Tube TYPE **PF CP 22**	IEC 61212	E-120	1,05 – 1,15	10

{*} According to related standard technical data sheet.

{**}According to IEC 60641-2 Subclause 20 in ENPAY Insulation and HV Test Laboratory.



Notation:

B.3.1 A
Pressboard - IEC 60641-3-1 TYPE B.3.1 A

PF CP 202
Resin Bonded Laminated Sheets
IEC 60893-3-4 TYPE PF CP 202 – DIN 7735 HP 2061.5

PF CP 22
Round Laminated Rolled Tube
IEC 61212-3-1 TYPE PF CP 22

Oil impregnated Pressboards have a big advantage compare (technical and economical) with non oil impregnable resin bonded papers which are no more used in oil transformers.
We recommend changing old tradition in some CIS countries and to use the Pressboard cylinders in state of resin bonded cylinders in Oil immersed Power Transformers.

b. Comparison of Laminated Board with Laminated Wood [9] [12]

IEC 60763 – Laminated Board
Board built up from sheets of pressboard bonded with an adhesive.
IEC 60763-3-1 TYPE LB3.1A.1 (Casein)
IEC 60763-3-1 TYPE LB3.1A.2 (Polyester – Non Aqueous)
IEC 61061 – Laminated wood

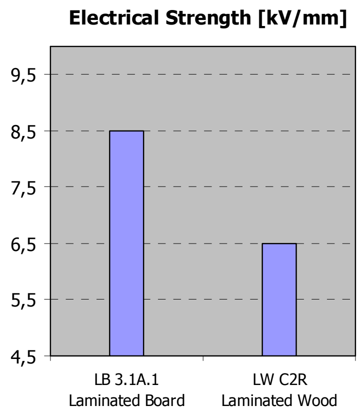
Comparison Table

Definition	Standard	Thermal Class [°C]	Density [g/cm^3]	Electrical Strength [kV/mm]	Flexural Strength MD [MPa]	Flexural Strength CMD [MPa]
Laminated Board Polyester TYPE **LB 3.1A.2**	IEC 60763	A-105	1,15 – 1,35	8,5{*}	140{*}	110{*}
Laminated Wood TYPE **LW C2R**	IEC 61061	A-105	0,90 – 1.10	6,5{*}	140{*}	70{*}

{*}According to IEC 60763-2 Subclause 8.2.1 in ENPAY Insulation and HV Test Laboratory.

IEC 61061 TYPE C2R

Laminated Board



Notation:

LB 3.1A.1
Laminated Board IEC 60763-3-1
TYPE LB3.1A.2

LW C2R

Some Important Results of Laboratory Tests and experiences:

Laminated board has much higher partial discharge inception voltage, better drying and oil impregnation feature, better aging behavior. Laminated wood gives corrosive acids during drying process in oven. As alternative to Laminated Board it has many negative points especially in HV Power Transformers. Laminated wood deteriorates mechanically more rapidly.

Conclusion:

In conclusion we can say that optimized design of the Insulation Systems and using of modern insulation components reduces the cost of Power Transformers significantly. It is not necessary to compromise the quality and volume of transformers. A reduction of the oil volume and in consequence a smaller transformer size can be achieved as a result of using optimized Insulation Systems.

Barrier systems provide big advantages same as lead exits, in terms of optimization with perfect dielectric strength and make whole system safer. Old conventional system of lead exits without barriers but only with paper wrapped conductor and single wide oil gap has many disadvantages compared to the new, state of the art barrier systems.

The Pressboard sheets and cylinders have a good oil impregnation characteristic so better electrical strength and better aging behavior compared with resin bonded sheets and cylinders.

The laminated press board compared with laminated wood shows significantly better electrical and aging behavior.

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