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Magnetic and Insulation Solutions for HV Power Transformers and Gapped-Core Reactors, Selim Yurekten

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MAGNETIC AND INSULATION SOLUTIONS FOR HV POWER TRANSFORMERS AND GAPPED-CORE REACTORS

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Enpay Transformer Components

SUMMARY

Enpay Core competence is the development and production of tailor-made (components) magnetic cores and wide range of insulation solutions with Cellulose based materials for Transformers and Reactors. The Transformer and Reactor producers need challenges and solutions from reliable component suppliers.

Key words: Power transformer, reactor, fringing flux, core, bevel edge core packets, tank shunts, stray losses, Transformerboard, compatibility test, Insulation, snauts, lead exit

INTRODUCTION

Enpay developed new systems and components to better deal with the manufacturing difficulties. This paper focused on the following products: [1]

A. MAGNETIC
1. CORES FOR TRANSFORMERS
2. GAPPED-CORES FOR SHUNT REACTORS
3. TANK AND CORE SHUNTS

B.INSULATION
1. TRANSFORMERBOARD
2. INSULATION COMPONENTS, SYSTEMS

A.MAGNETİC

1. CORES FOR TRANSFORMERS

In order to achieve the core quality, manufacturing challenges are needed. The most important is handling of silicon steel (CRGO).

State-of-the-art manufacturing processes can reduce the core losses and magnetostrictions. [1]

Major criteria's for the quality of CRGO are listed below:

-The losses
-Saturation inductions
-Magnetostrictions
-Surface insulation (carlite layer) Franklin value <230 mA
-Mechanical conditions
-Surface impurity
-Thickness tolerances

To clarify these points, at least the following tests must be done before cutting follcoils:

1-Measurement of losses (single sheet tests-according IEC 60404-3)
2-Online measurement of thickness during slitting of full coils
3-Online determination of cosmetic errors, rust, welding zone, tears-holes during slitting of full coils.

There are 2 negative impacts during handling of materials:

a. Plastic stress

Processing operations like slitting, shearing, notching etc. induce plastic stresses. This is generally unavoidable. However, it is controllable to minimum level through careful adjustments of processing machines.

b. Compressive stress

CRGO has good magnetic characteristic properties in the rolling direction. The magnetic properties are deteriorated if compressive stress is applied to the Rolling direction. The compressive stress increases the iron loss.

Core Losses are occurred by Hysteresis Losses and eddy current losses.

ENPAY manufactures the different type of cores for transformers. The picture shows 5-leg step-lap core for a power transformer.

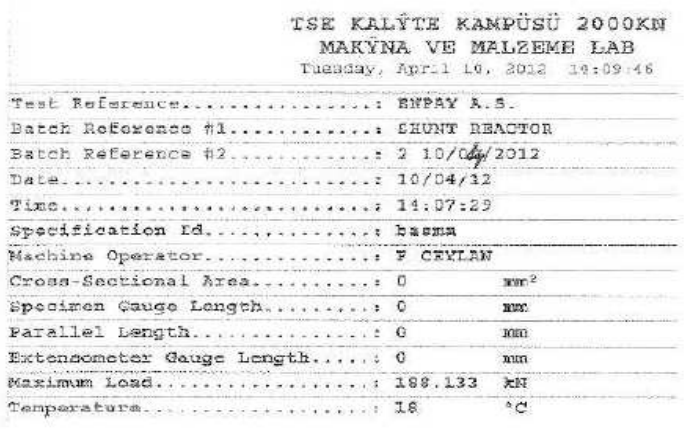
2. GAPPED-CORES FOR SHUNT REACTORS

There are radially stacked core sheets glued together with a suitable resin. Core limbs must be robust enough against to short circuits. In order to confirm the mechanical stability and robustness of the core packets we performed mechanical shock tests in the independent laboratory.

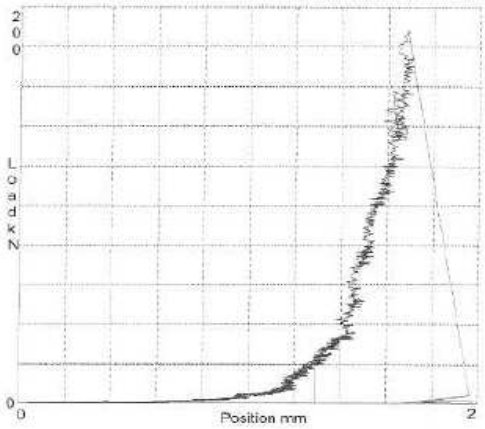
Mechanical Shock Test of Shunt Reactor Core Packet

Scope of Test	Pressure testing of the core package with ceramic discs which compares with reactor gapped core limb.
Test Conditions	Room temperature 20 ±3 [℃]
Test Method	Determination of Flexural Strength Test or 3. Point Bending Test
Sample Dimensions	D [Ø] = 660 [mm] h= 210 [mm] Without glass bandage D [Ø] = 660 [mm] h= 210 [mm] With glass bandage
Test Results	188,13 [kN] without glass bandage 357,13 [kN] with glass bandage

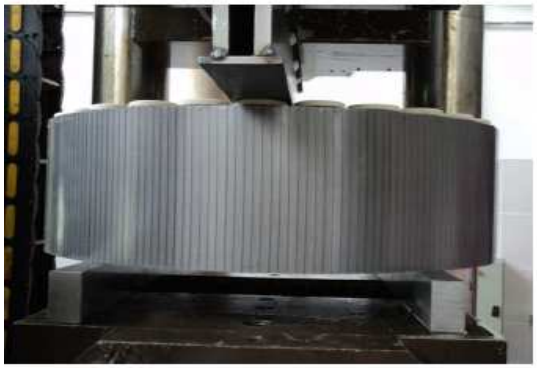
Core Packet without Glass Bandage

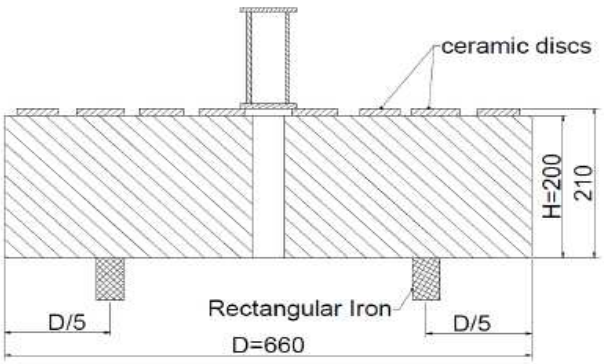

TSE KALİTE KAMPÜSÜ 2000KN
MAKİNA VE MALZEME LAB
Tuesday, April 10, 2012 10:09:46

Test Reference	ENPAY A.S.	
Batch Reference #1	SHUNT REACTOR	
Batch Reference #2	2 10/04/2012	
Date	10/04/12	
Time	11:07:29	
Specification Id.	basma	
Machine Operator	F CEYLAN	
Cross-Sectional Area	0	mm²
Specimen Gauge Length	0	mm
Parallel Length	0	mm
Extensometer Gauge Length	0	mm
Maximum Load	188.133	kN
Temperature	18	°C



Without glass bandage

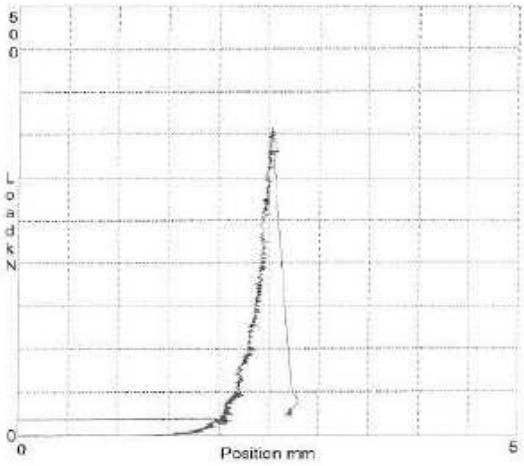

Max. Load 188,13 kN



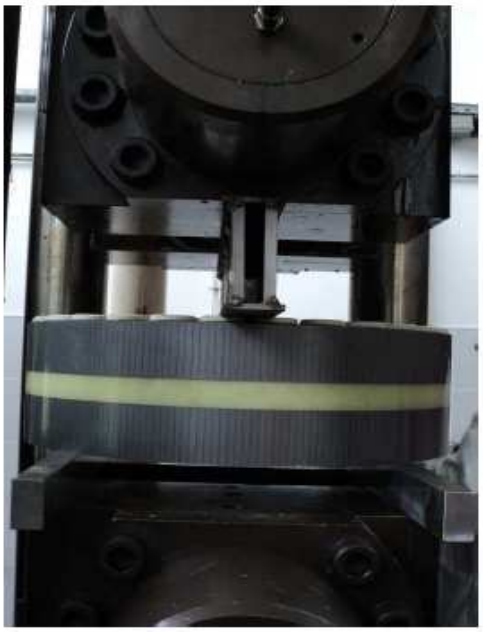
Core Packet with Glass Bandage

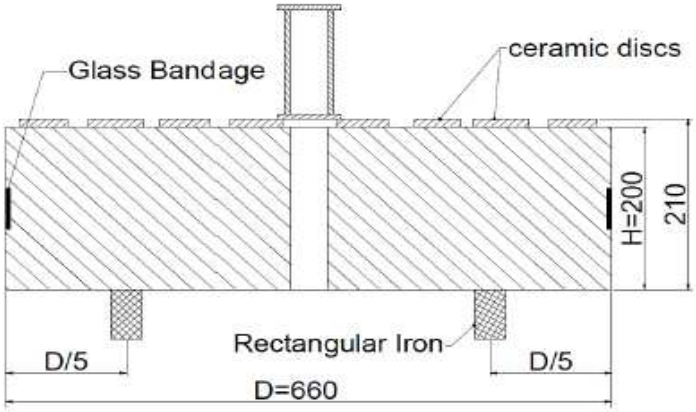
TSE KALYTE KAMPÜSÜ 2000KN
MAKÝNA VE MALZEME LAB
Tuesday, April 10, 2012 13:31:33

Test Reference	ENPAY A.S.	
Batch Reference #1	SHUNT REACTOR	
Batch Reference #2	1 10/04/2012	
Date	10/04/12	
Time	13:24:46	
Specification Id	baama	
Machine Operator	F CEYLAN	
Cross-Sectional Area	0	mm²
Specimen Gauge Length	0	mm
Parallel Length	0	mm
Extensometer Gauge Length	25	mm
Maximum Load	357.333	kN
Temperature	18	°C



With glass bandage





Max. Load 357,33 kN

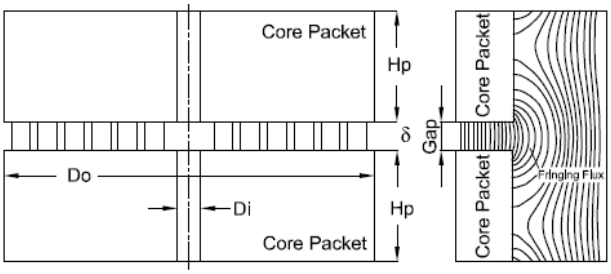
Results of these two tests are specified as below;

The shunt reactor core packet without glass bandage cannot be able to resist to short circuits and also because of that the life of shunt reactor gets shorter.

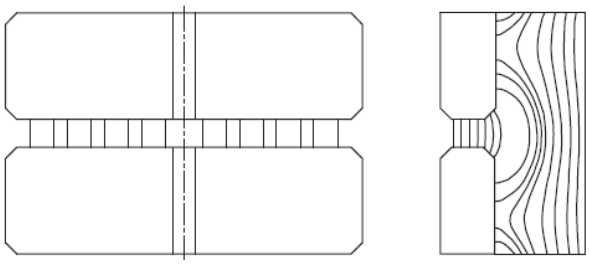
Core packets with glass bandage compare with non bandage have bigger mechanical strength according to test results. Today and in the future the grids will need bigger power and higher voltages up to 1200 kV. For this development core packets with glass bandage will bring big advantages.

Discs of a special ceramics glued together with the core packets provide the exact distance required. This type of cores can be used also in magnetically controlled shunt reactors.

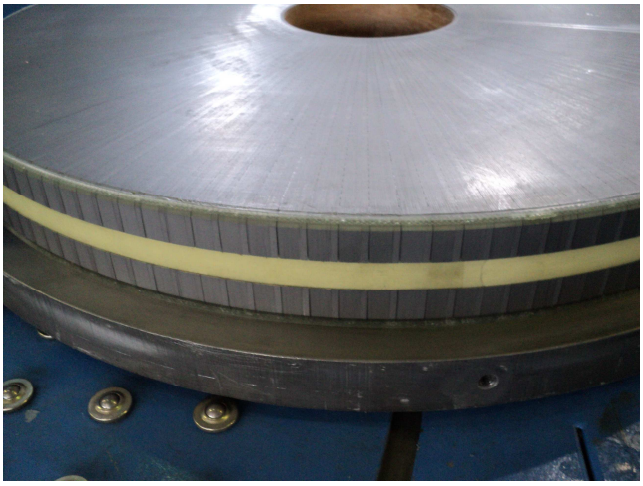
Radially stacked cores prevent fringing flux-eddy currents from entering flat surfaces of core steel, thereby avoiding overheating. In order to reduce eddy current losses, beveled edge core packets are developed during recent years. This provides the production of a more economical reactor (core packet with a smaller diameter). [4], [5]



Sharp Edge Core Packets



Bevel Edge Core Packets

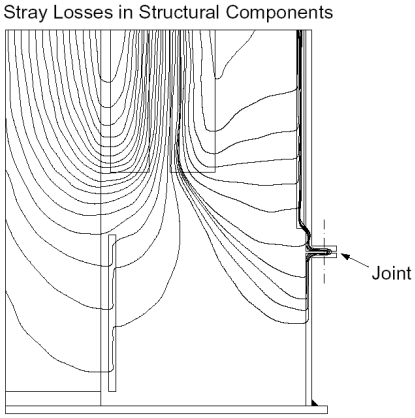


It is another challenge that the optimizing of additional ring yoke, as a magnetic shunt. With this solution the additional losses can be reduced up to 10 % of the copper losses.

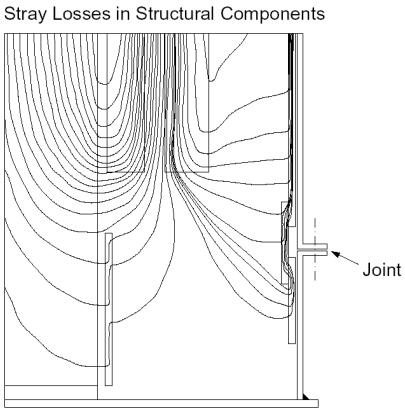
Core Limb for 1200 kV 300 MVAR shunt reactor

3-TANK AND CORE SHUNTS

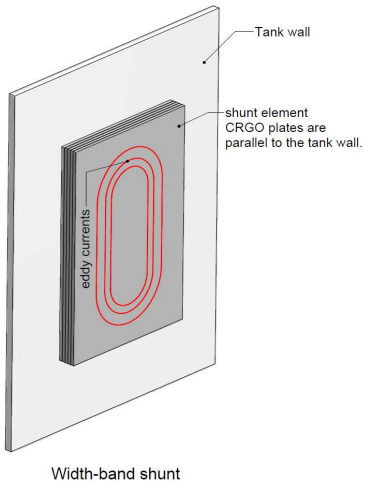
The figure shows us Leakage field in a transformer. The leakage impedance of a transformer is one of the most important specifications. Stray (eddy current) losses in structural components are calculated now with 3D finite element method (FEM).A major portion of these stray losses occurs in tank and core clamping elements. The magnetic shunts are more effective in controlling stray losses as compared to the non- magnetic shields like aluminum or copper shields. [1], [6]



Leakage field plot for bell tank

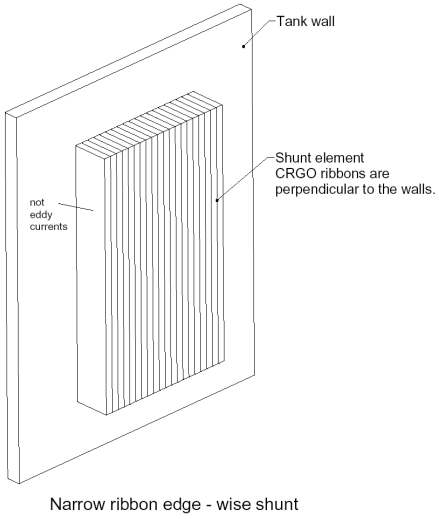


Leakage field plot for bell tank with additional shunts in vessel



Width-band shunt

Not use today, less effective as compared to the edge –wise shunt



Narrow ribbon edge - wise shunt

State –of-the-art technology a substantial reduction in tank stray losses

Assembling of the shunts on the tank wall

Assembled and painted (oil resistant special painting material) tank inside

B. INSULATION

1 - TRANSFORMERBOARD

The life of transformer depends on the life of insulation. Insulation in liquid immersed HV power transformers is cellulose based material. It is the best and the most cost effective insulation.[6]

Transformerboard is manufactured from unbleached sulphate cellulose PULP in HOT PRES PROCESSES, state-of-the-art technology. Precise testing facilities and extensive quality controls are essential in order to guarantee best quality of board material. To measure on-line a lot of detectors are installed on the system. These are metal detectors, moisture and density measurements, surface inspection control system, thickness measurement, etc…

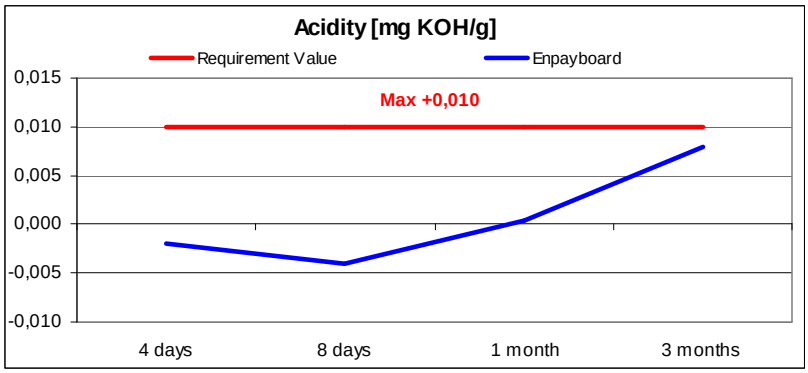
Oil and Transformerboard are affected from each other. In order to clarify the situation, contamination (compatibility) test should be carried. [7]

Compatibility Test of Pressboard with Transformer Oil

To check the behavior of Transformerboard and oil during the life of transformer in service should be carried out with contamination test. The following criteria's of Compatibility test are measured on the oil before and after the relevant test duration.

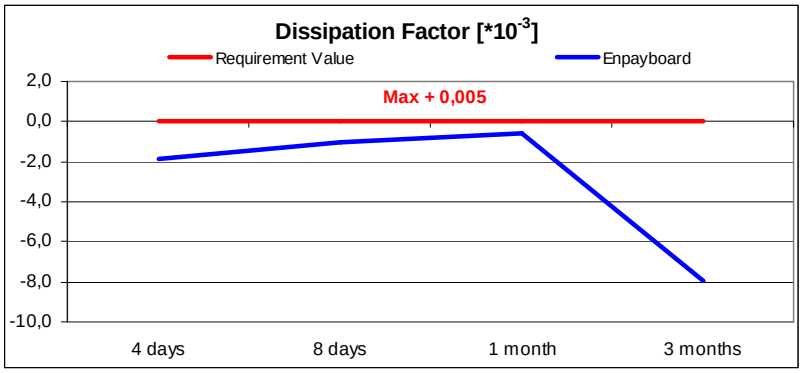
Acceptance criteria of below tests are determined according to 3 months test period. If test period is extended, acceptance criteria should be revised.

Acidity (IEC 62021)



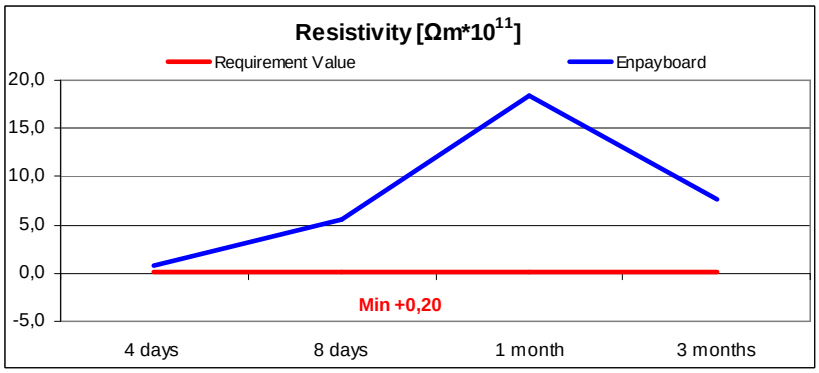
The increase of value of acidity in transformer oil causes rapid aging of all cellulose materials in transformer in the long term.

Dissipation Factor (IEC 60247)



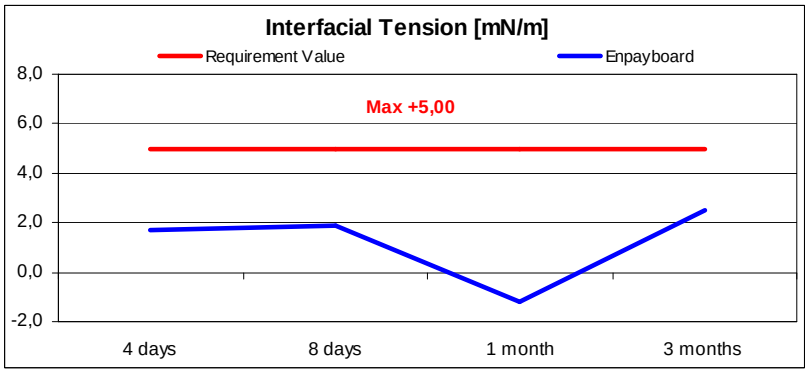
Dissipation factor is closely related with cellulose quality and cellulose of poor quality usage causes increase in Dissipation Factor of transformer oil and accelerates sloughing of transformer oil.

Resistivity (IEC 60247)



There is a close relation between Dissipation Factor test and Resistivity. The pollution from the pressboard in the transformer oil causes the resistivity value to decrease.

Interfacial Tension (ASTM D 971)



Decrease of IFT value shows not only the increase of contamination but also the sludge formation in transformer oil.

2 - INSULATION COMPONENTS, SYSTEMS

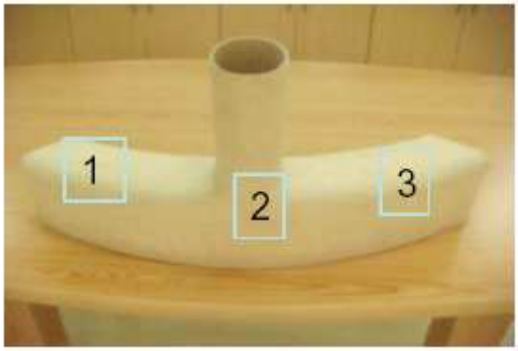
In insulation design, field stress distribution between liquid impregnated solid insulation is taken as the fundamental criteria. Due to analyzing electrical field distribution can be find the best solution.

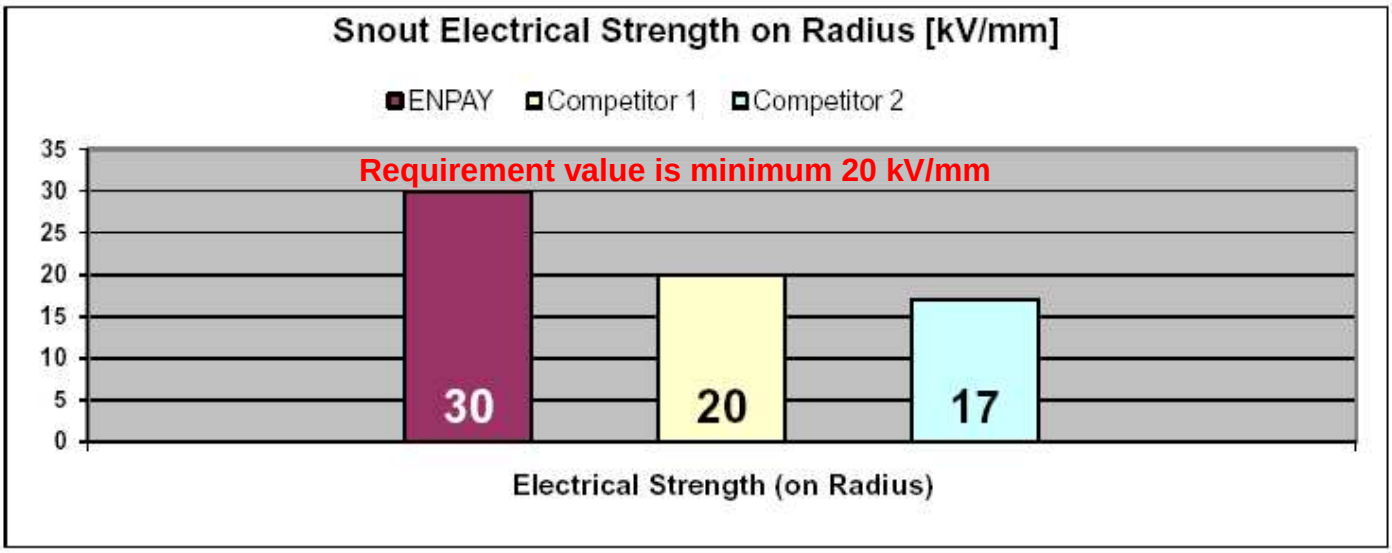
Modern Power Transformer Producers prefer to obtain the components from sup supplier because both partners can concentrate on their core competence. Transformer producer can realize in this way better quality, lower costs, and state-of-the-art-technology.[8]

Moulded components like snouts, angle ring sectors, and caps produced tailor made according customer needs. Some of specifications from different suppliers are shown in the table below. Test points are on radius point.

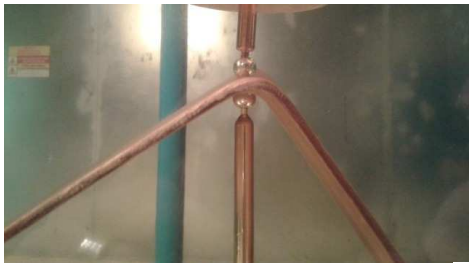
Snout Test Results Comparison Table

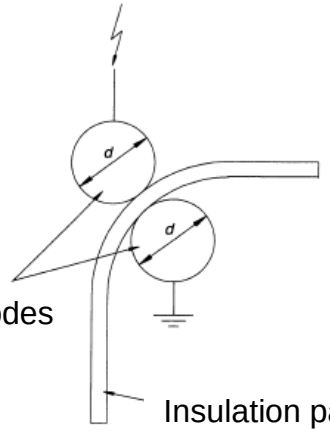
Property	Unit	ENPAY	Comp.1	Comp.2
Apparent density	[g/cm³]	0,69	0,69	1,00
Ash content	[%]	0,30	0,30	0,53
Oil absorption	[%]	72	69	28
Electrical Strength (Radius)	[kV/mm]	30	20	17





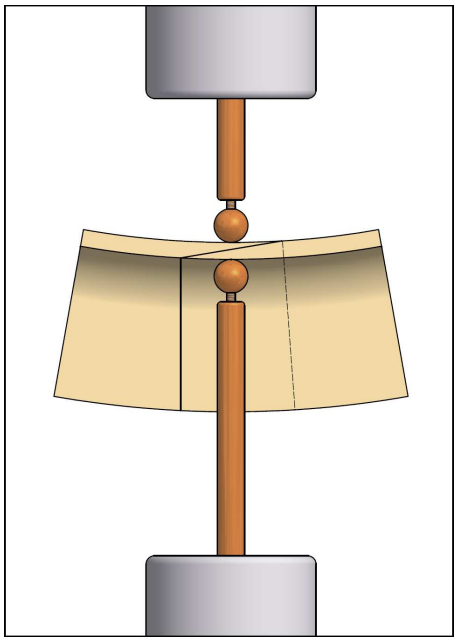
Caps or Angle Rings – Comparison Results In terms of Breakdown Voltage

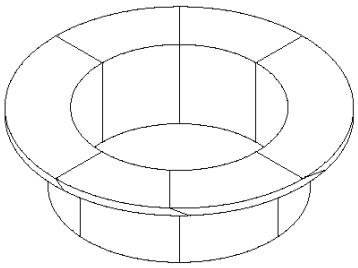




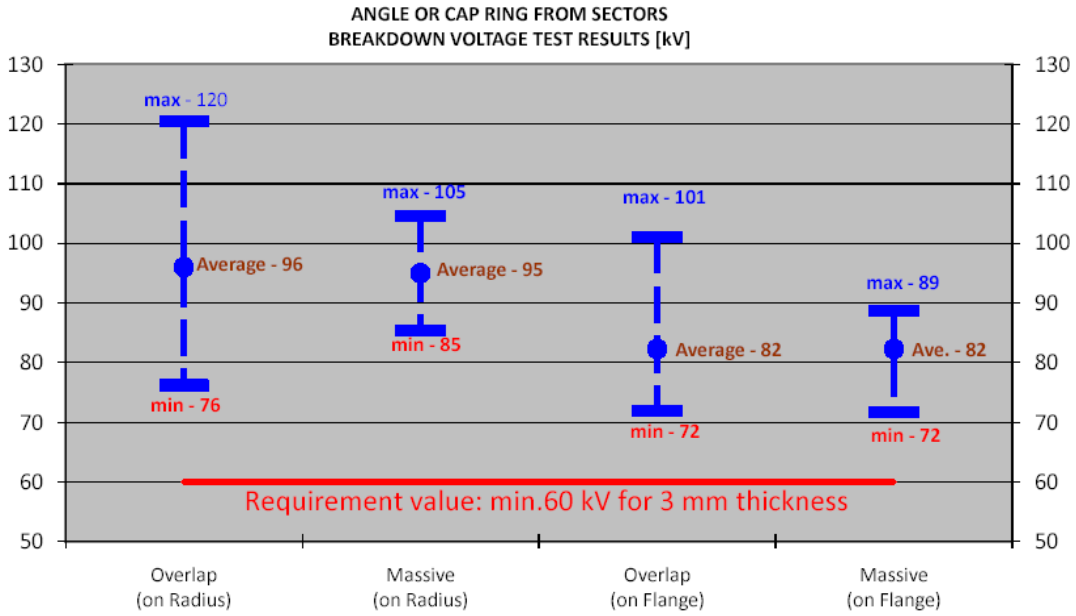
Electrodes

Insulation part
IEC 022/98





Below are the test results of breakdown voltage in the overlapping and massive parts of angle rings that have been formed by adhesing the sectors. Even in the most critical part -the radius part – breakdown test results are higher than the value should be.

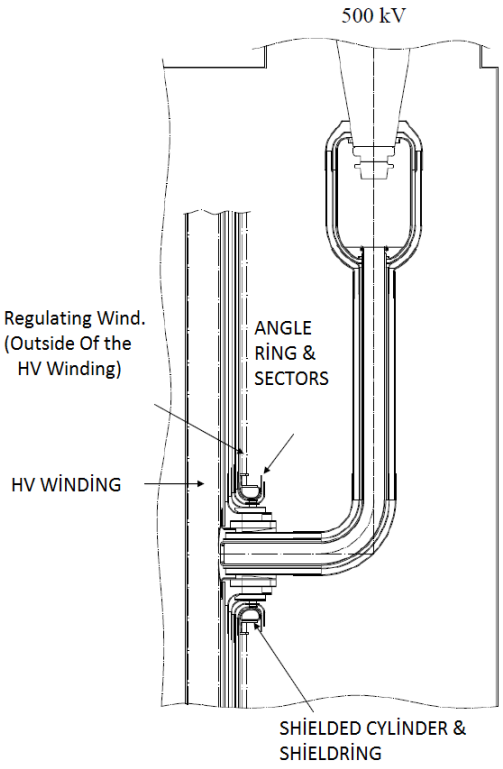


One of the most important parts of insulation components is Lead-Exit. Best solution is lead exit with barrier system. Total cost compare with conventional type is less. On the other hand the barrier systems as lead exits are making your transformer life longer. [9], [10]

Conventional lead exits with craft (crepe) paper wrapped main conductor and single wide oil gap have anomalous breakdowns and so that big RISK. This is not an economical solution. [11]

This information is very important for Grids also.

Position of 550 kV lead exit with barrier system in the Tank Connection to winding at the top



-500 kV Middle Exit Solution for Outside Regulating Winding

CONCLUSION

New manufacturing solutions and designs for components help transformer optimization. The paper provides in which major areas for transformers and reactors are most important study and design, general requests for core design.

Gapped cores with bevel edge limbs and additional ring yokes are state-of-the-art manufacturing for new type shunt reactors. The already produced biggest units are for UHV 1200 kV. 300 MVAR. This is the highest voltage level worldwide.

Furthermore the development of the core and tank shilding technology for modern power transformers gives more information about the details. Due to usage of the modern edge-wise magnetic shunts, magnetic losses and cost of transformer can be reduced and better quality can be achieved.

The quality of Transformerboard prolongs life of transformer. Rough material of that is unbleached sulphate cellulose PULP. Transformerboard is manufactured in HOT PRESS PROCESS with state-of-the-art technology.

Compatibility test of Transformerboard with oil is presented with curves.

Electrical strength test results from snauts shows differences values from different supplier.

Angle ring and caps sector tested up to breakdown voltage in different points. In overlapping places there isn’t any kind of risks compare with full rings.

Lead exits with barrier system are the best solution. Because conventional types with paper wrapped main conductor and single wide oil gap are risky and not economical solution.

Insulation components allow for less production costs and decreased manufacturing cycle time of power transformer production. There are a lot of technical and economical advantages to use the kits (packages).

There is indeed a need for theoretical knowledge and R&D in production, however the products must be reliable, thus a sustainable high quality level in production must be achieved.

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