ENPAY
Transformer Components

THE FUTURE OF THE POWER SYSTEMS AND THE ELECTROMECHANICAL INDUSTRY'S ROLE

GÜÇ SİSTEMLERİNİN GELECEĞİ VE ELEKTROMEKANİK ENDÜSTRİSİNİN ROLÜ

TREND IN THE RECENT IMPROVEMENT OF TRANSFORMER-REACTOR COMPONENTS

TRAFO-REAKTÖR KOMPONENTLERİNDE SON GELİŞMELER

Selim Yürekten, Enpay Transformer Components

CIGRE-16 NOVEMBER 2015, İTÜ İSTANBUL-TR

INDIA

TURKEY

SLOVAKIA

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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Global competition of the HV Power Transformer producers is getting more difficult.

One of the most important challenges to reduce the cost of transformer is the optimization of magnetic core and insulation components design.

Successful performance can be achieved by well established cost effective design criteria and by high quality manufacturing of the components.

The present study gives general information about specification of main components for different type of power transformers and reactors.

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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1. INSULATION COMPONENTS
2. MAGNETIC COMPONENTS
3. CT. FOR BUSHINGS
4. QUALITY

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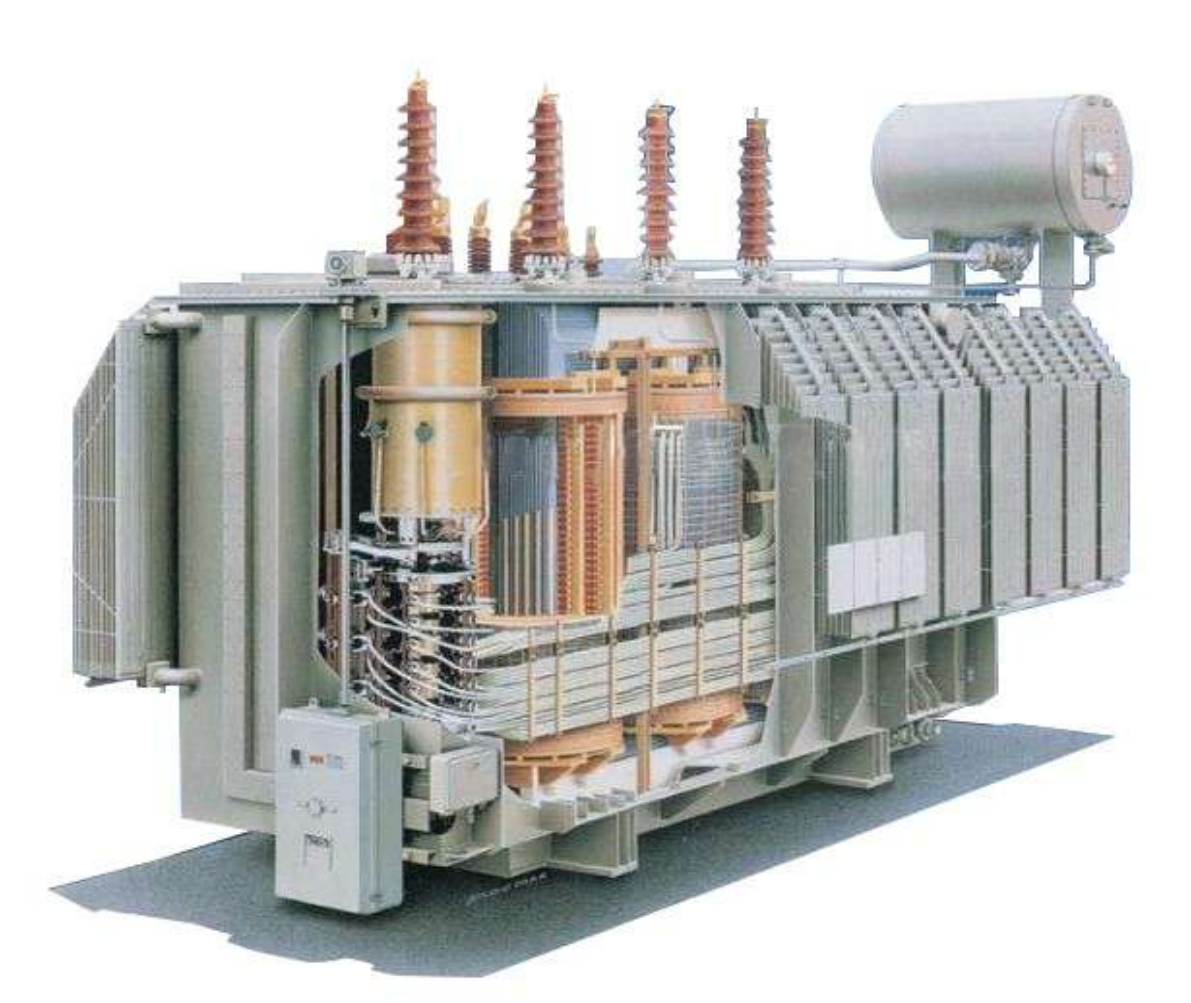
HV POWER TRANSFORMER



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1. INSULATION COMPONENTS

1A. TRANSFORMERBOARD, IEC 60641

1B. LAMINATEDBOARD, IEC 60763

1C. COMPONENTS FROM BOARD MATERIAL

1D. COMPONENTS FROM WET MATERIAL

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1A. TRANSFORMERBOARD, IEC 60641

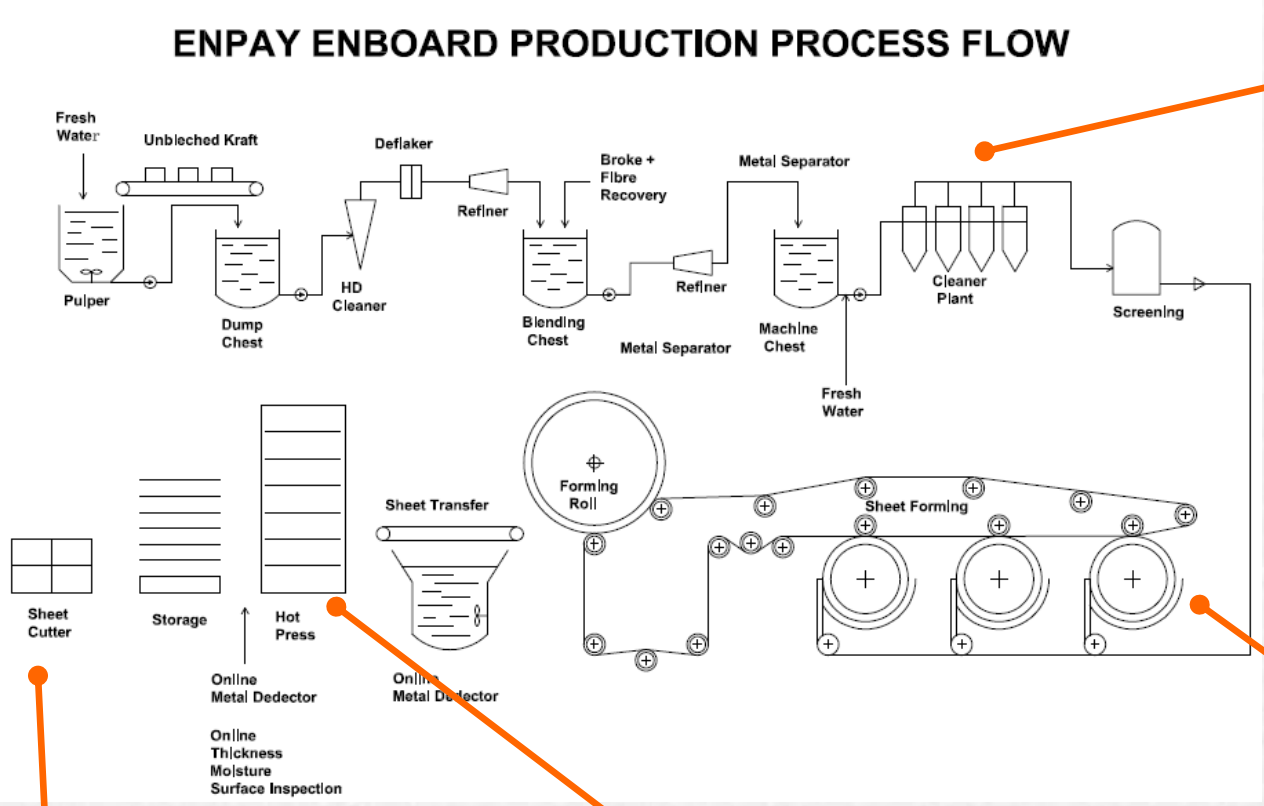
The Life of transformer depends on the life of insulation.

Insulation in liquid immersed HV power transformers is cellulose based material.

-Manufactured from unbleached sulphate cellulose PULP in HOT PRES

Sheet size from board machine 6300x3200 x1-8 mm.
Worldwide reachable biggest size.

ENPAYBOARD® Production Hall



I.Stock Preparation

II.Board Machine

III.Hot Press

IV.Trimming and Sizing

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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I.Stock Preparation

II.Board Machine

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III.Hot Press

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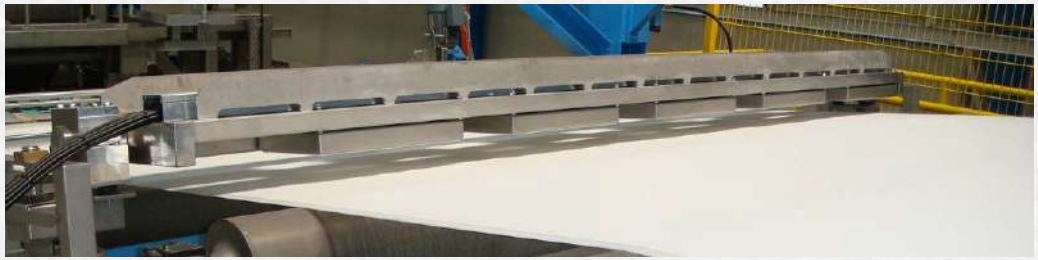
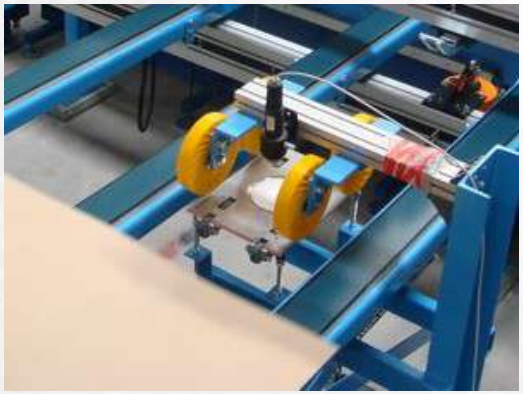
ENPAYBOARD® ONLINE CONTROL STEPS

1. Metal Dedector (Wet Material)

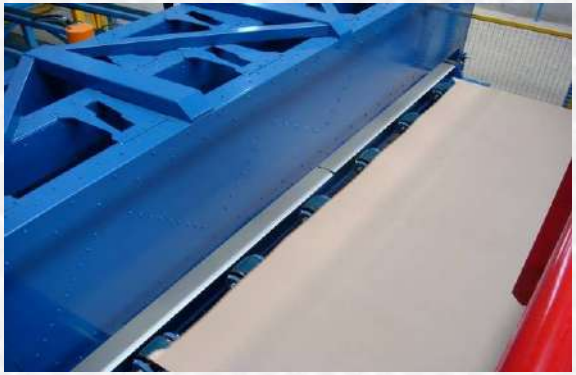


2. Moisture Content

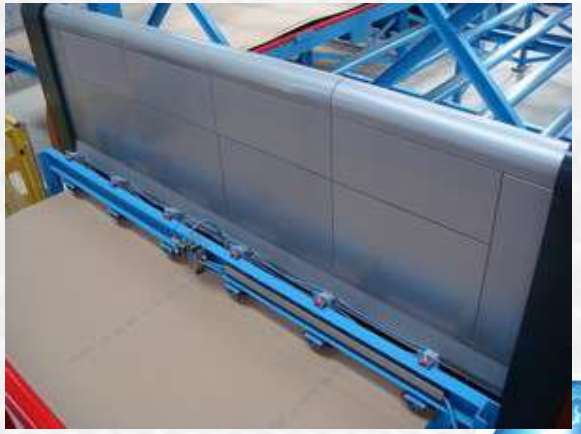


3. Thickness

4. Metal Dedector



5.Surface Inspection



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1B. LAMINATED PRESSBOARD, IEC 60763

-With casein glue (TYPE LB 3.1A.1)

Sheet sizes

4000x2000x9-40 mm

3000x3000x9-40 mm

-With polyester resin glue (TYPE LB 3.1A.2)

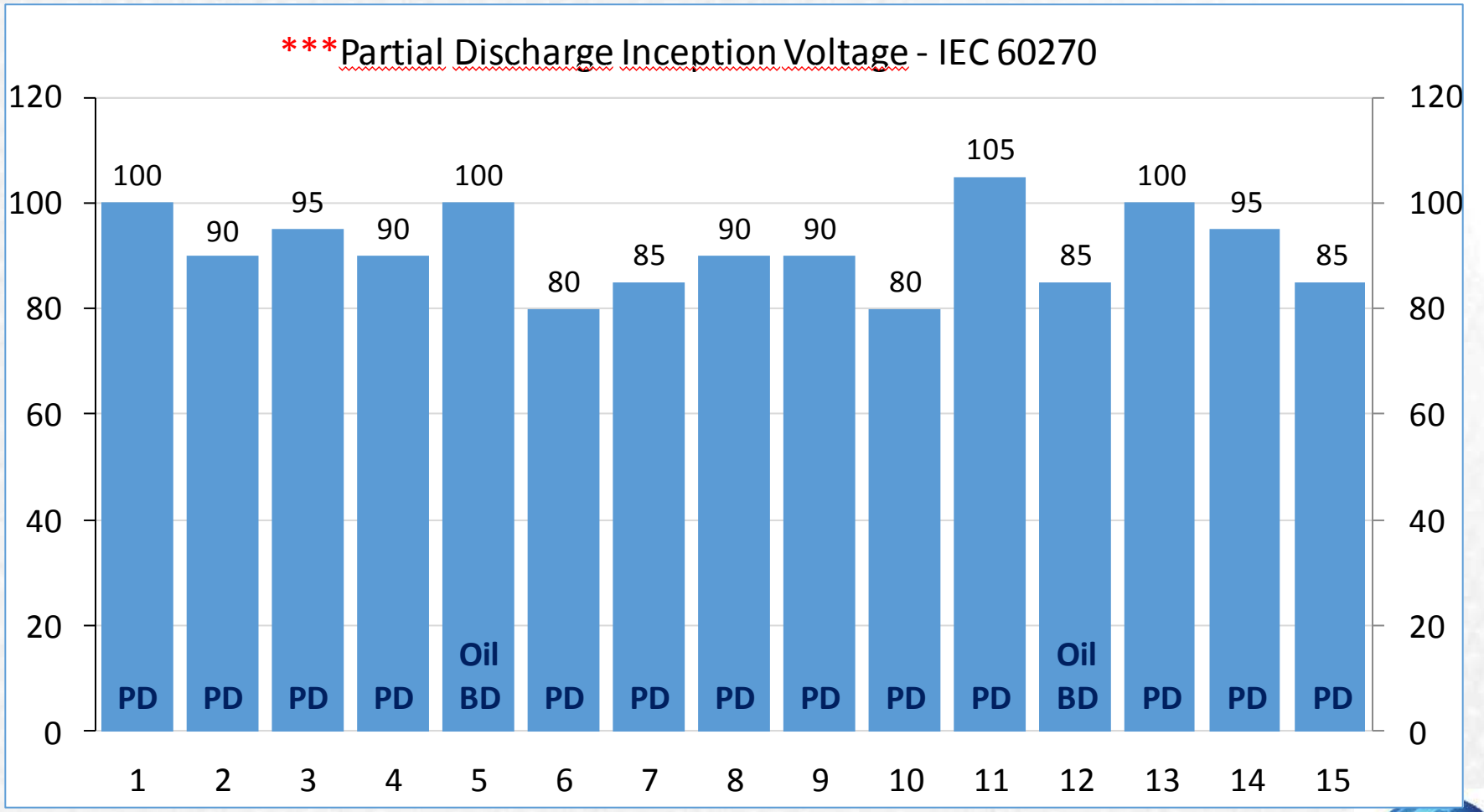
Sheet sizes

4000x2000x9-150 mm

3000x3000x9-150 mm

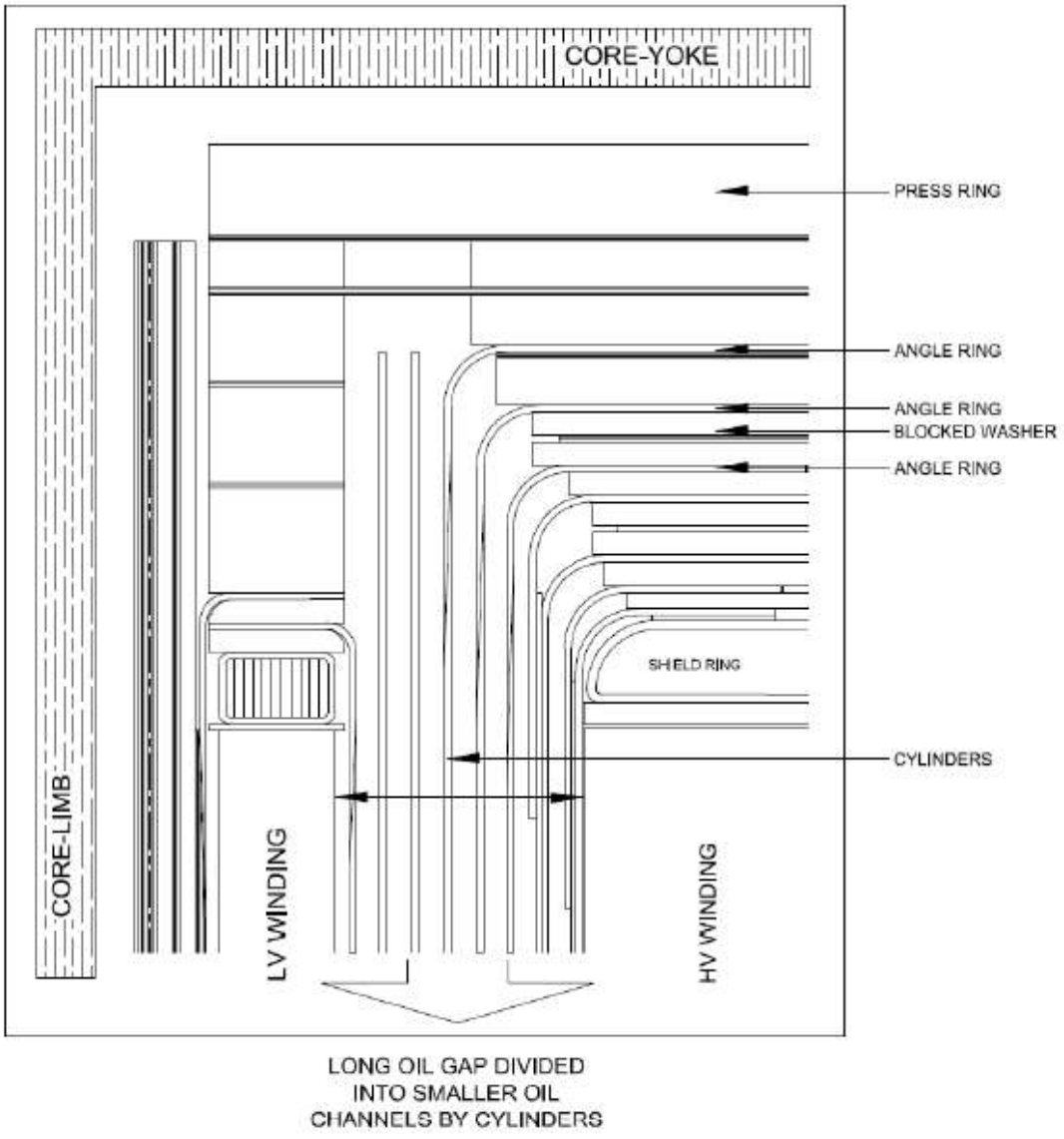
MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

Laminated Pressboard Polyester – IEC 60763-3-1 TYPE LB 3.1A.2



Requirement Value : 70 kV (10 mm - 7kV/mm)

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS



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

C. COMPONENTS FROM BOARD MATERIAL

Shield Rings (SCHIRMRING)

•Shielded Rings made of Laminated Wood or Transformerboard

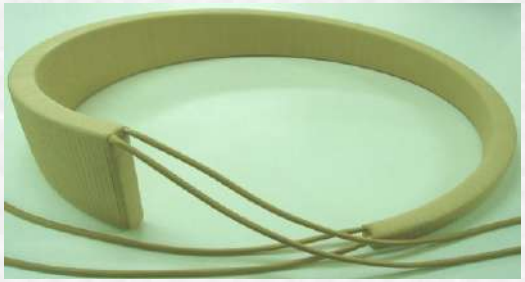
•According to IEC 60641-3-1 Type B.3.1-IEC 61061-3-1 Type C2R

Shield End Rings

The Rings are made of;

•Laminated Wood according to IEC 61061 or

•Laminated Pressboard according to IEC 60763



1C. COMPONENTS FROM BOARD MATERIAL

Press (Clamping) Rings

The Rings are made of Laminated Pressboard according to IEC 60763

Shield (Metallized) Cylinder - Axial

The Cylinders are made of Transformerboard according to IEC 60641

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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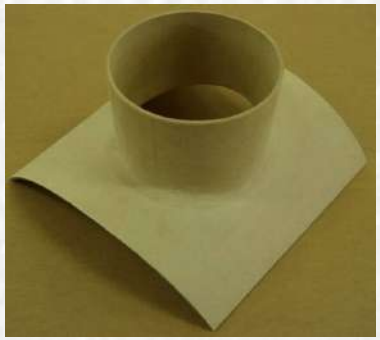
KITS for Power Transformers

- Cylinders made of Transformerboard
- According to IEC 60641-3-1 TYPE B.3.1
- Less production costs
- Decreased manufacturing cycle time
- According to customer request

1D. COMPONENTS FROM WET MATERIAL

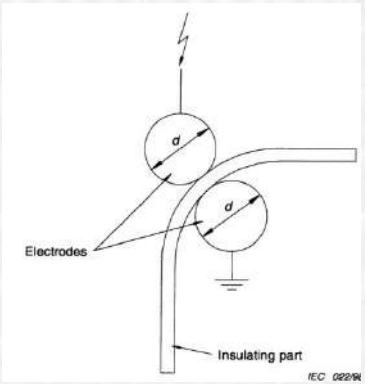
Snouts-Chimney Sectors-Flange Tubes

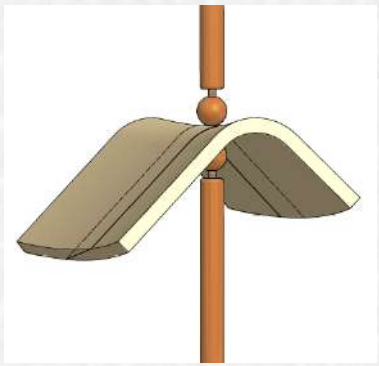
- Molded components made of Transformerboard according to IEC 60641
- Tailor-made according to the customer specification



D. COMPONENTS FROM WET MATERIAL

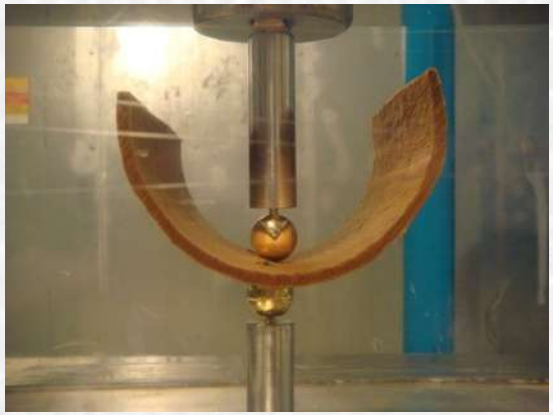
Caps or Angle Rings – Electrode Configuration for Breakdown Voltage According to IEC 60243

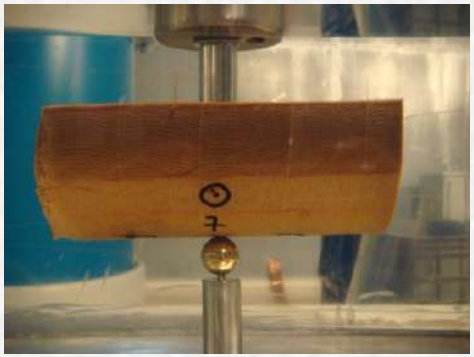


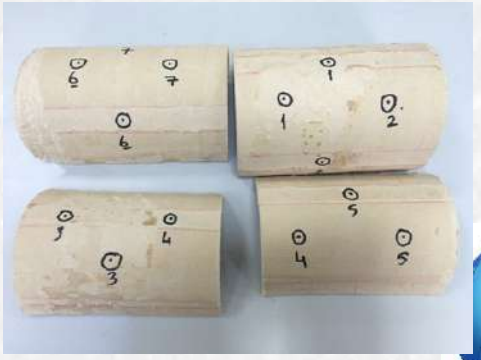


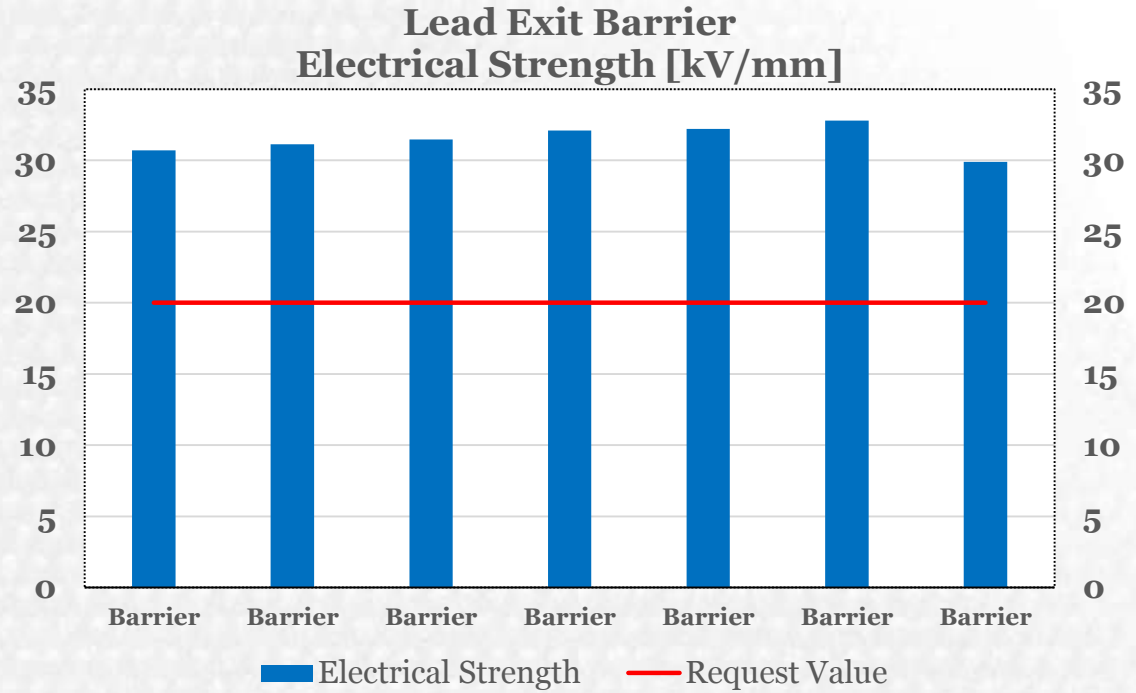
Electrode configuration according to IEC 60243

D. COMPONENTS FROM WET MATERIAL









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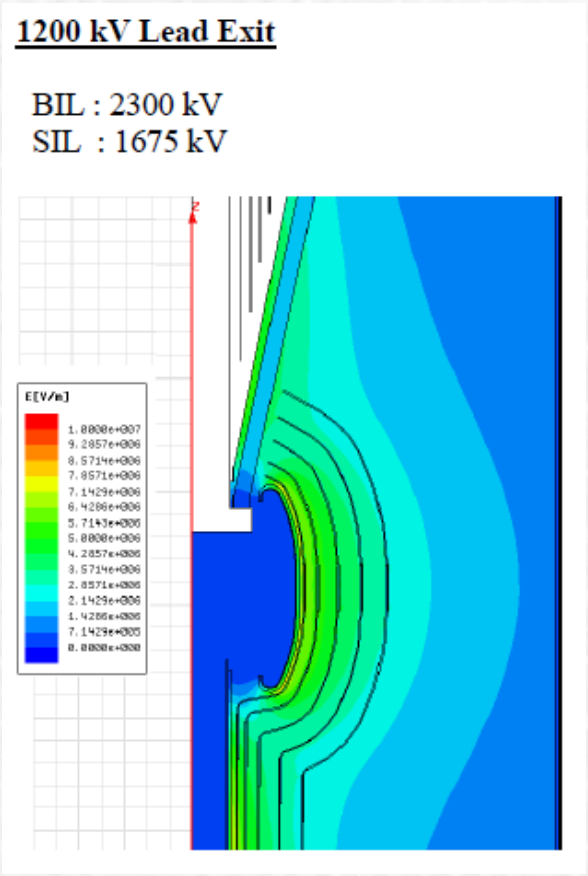
D. COMPONENTS FROM WET MATERIAL

Electrodes (Shields) for Bushings and Lead Exits

D.COMPONENTS FROM WET MATERIAL

1200 kV Lead Exit



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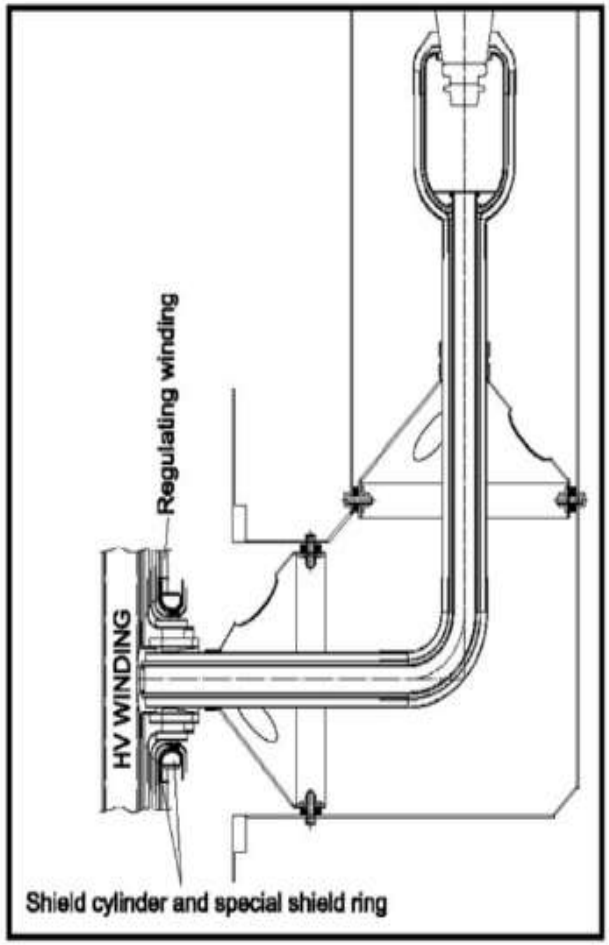
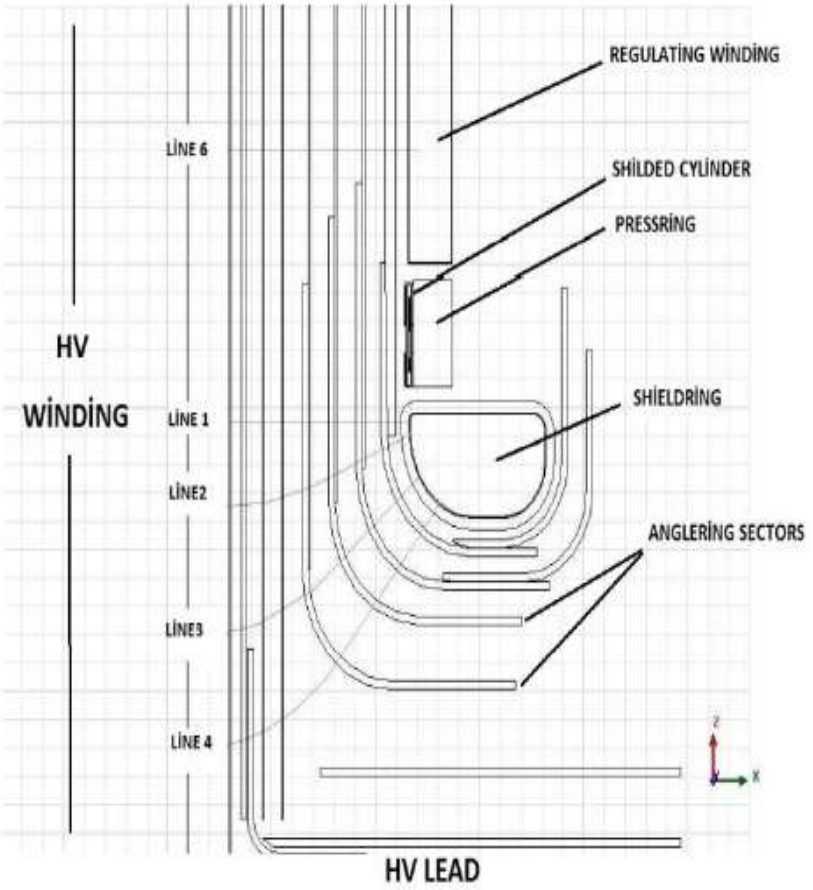
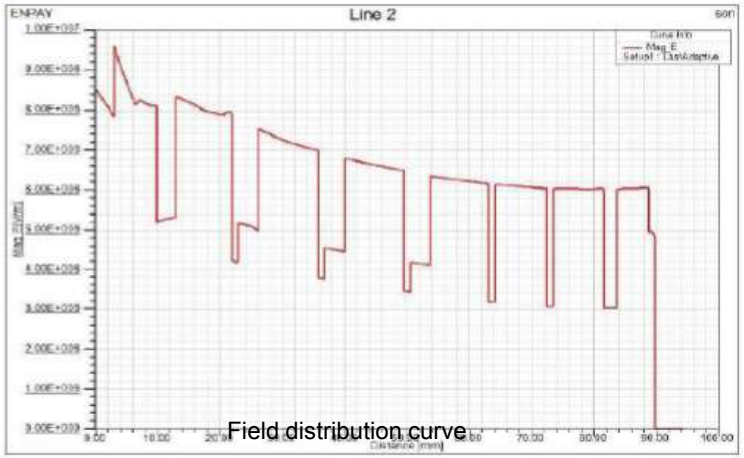
Middle exit system design

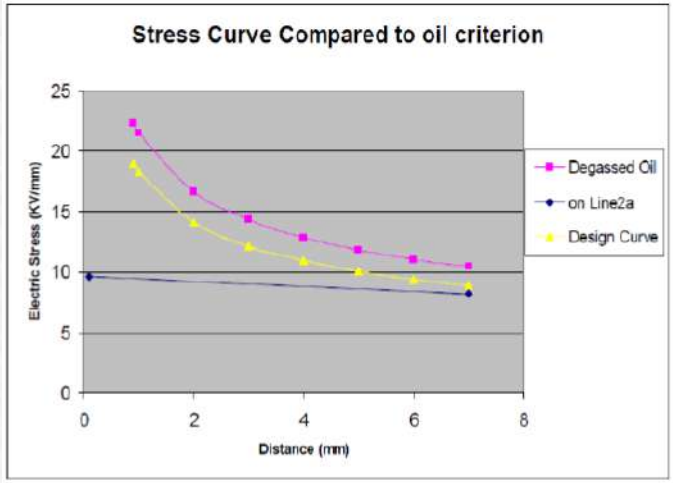


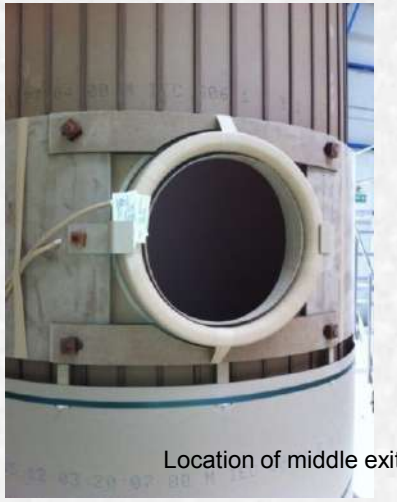


Middle exit system field distribution curve-stress curve



Field distribution curve





Location of middle exit transformer

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2. MAGNETIC COMPONENTS

2A. CORES FOR POWER TRANSFORMERS

2B. CORES FOR REACTORS

2C. TANK-JOKE SHILDINGS FOR TRANS. and REAC.

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2A. CORES FOR POWER TRANSFORMERS

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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2A. CORES FOR POWER TRANSFORMERS

Core loss = P(hys)+P(eddy + anomalous los.)

The detail of the hysteresis loss is given in hystresis loop.

$$P_h = K_2 f \, B_{mp}^{n}$$

Eddy current loss is given by

$$P_e = K_1 f^2 t^2 B_{rms}^2$$

Challenges for transformer industry

-design optimization

-low induction level

-core weight

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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For less core losses and magnetostrictions (noise) :

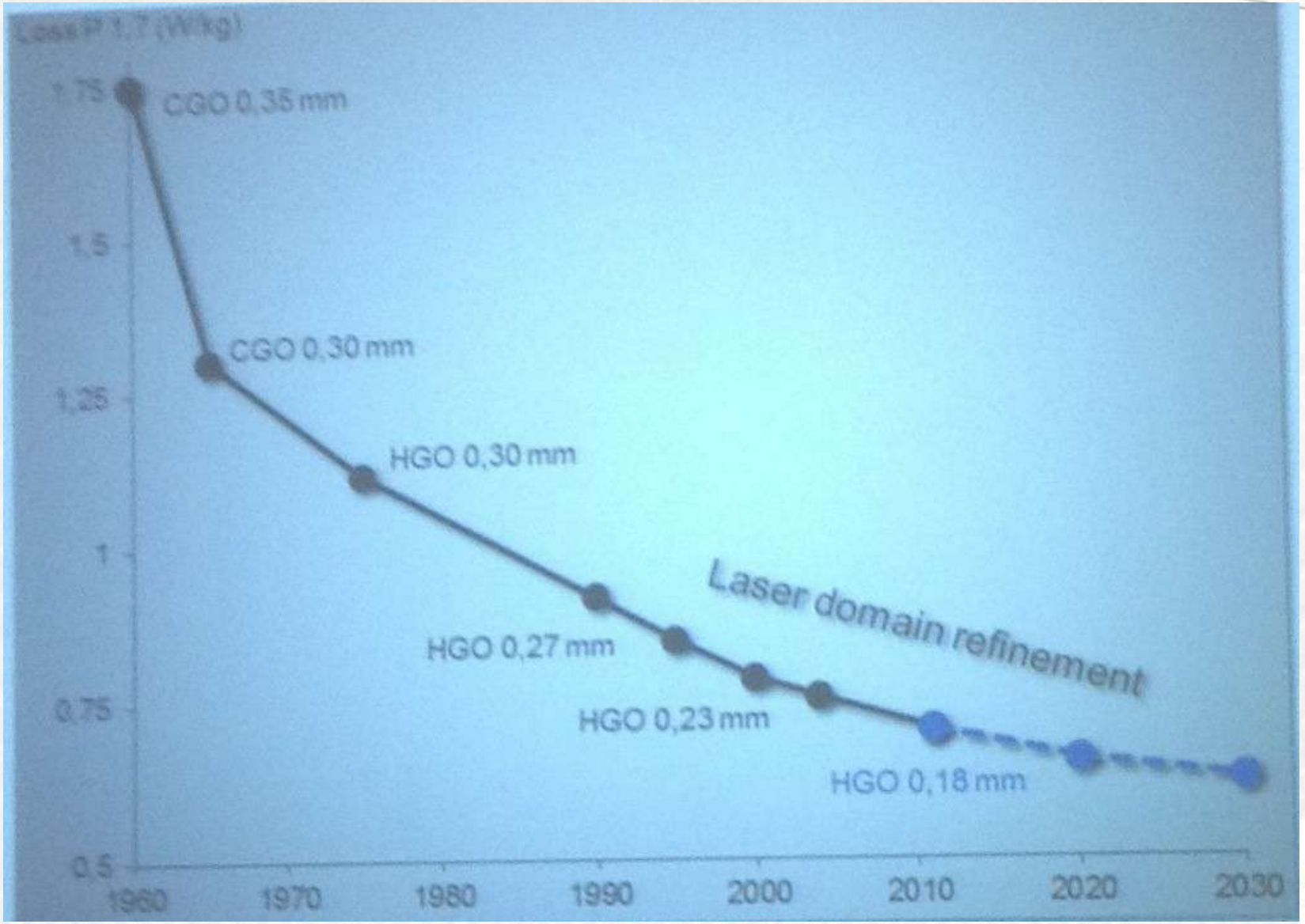
-state-of-the-art design and manufacturing

-optimized magnetic domain structure

-optimized insulation coating characteristics

-cost effective steel selection

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS



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2B. CORES FOR REACTORS / SHUNT REACTORS

Shunt reactors contain same components as power transformers. Difference is that reactor core limbs have non magnetic gaps (so called 'gapped-core')

Challenges for shunt reactor technology

-high stray loss create local overheating

- vibration create local overheating damage the insulation, and leakages of the tank

-high sound level required to apply expensive sound screen materials

-can be studied with (FEM) simulation programs

The stacked laminations prevent fringing flux, avoiding overheating on the core packed

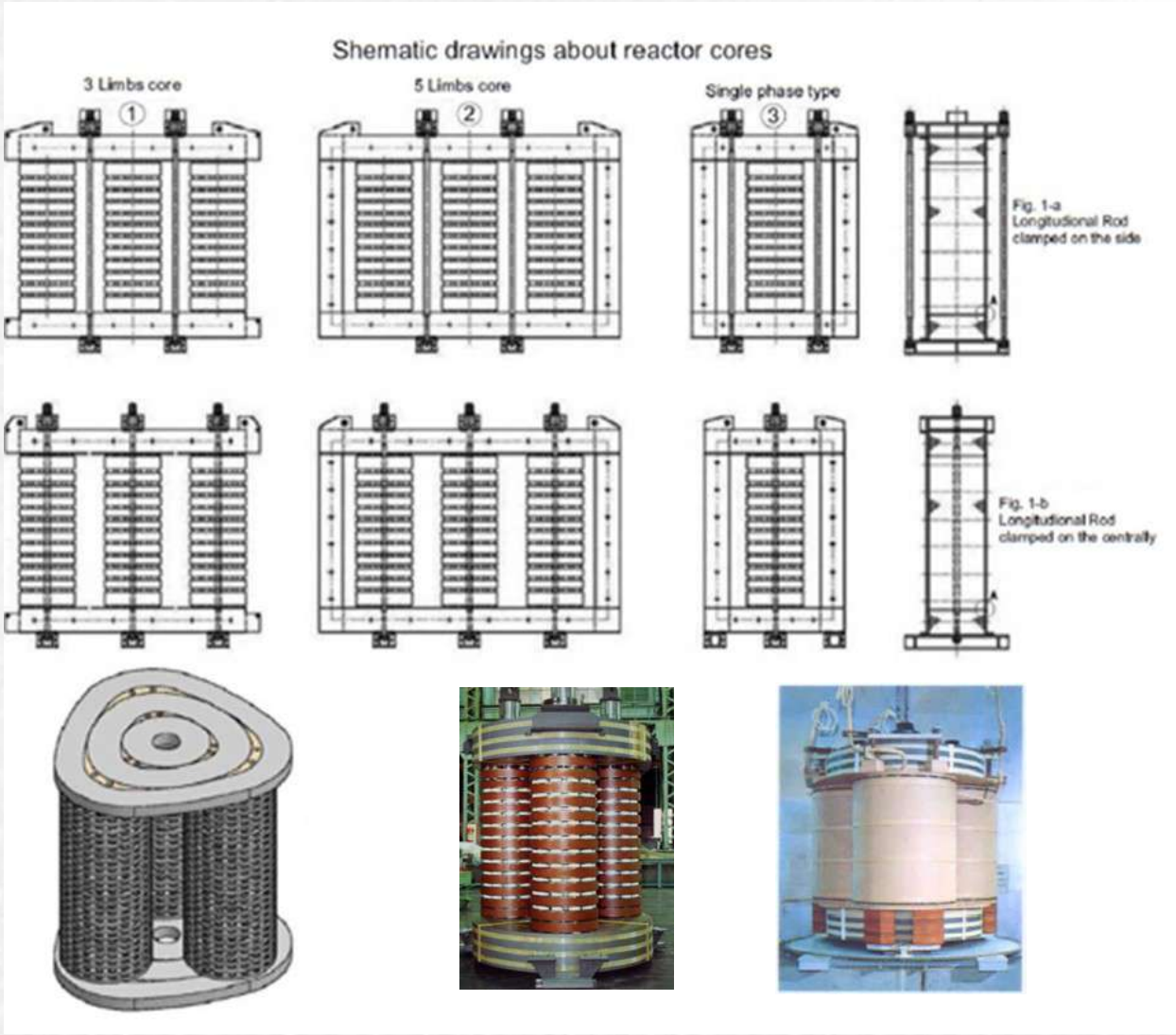
Fringing fluxes increase sound level

Losses of gapped core reactor are:

Winding losses + core losses in limbs and yokes+ additional(structural) losses by leakage flux

Core losses composed of 67% eddy current losses + 33% hysteresis losses

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS



MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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Shunt reactor cores from production line

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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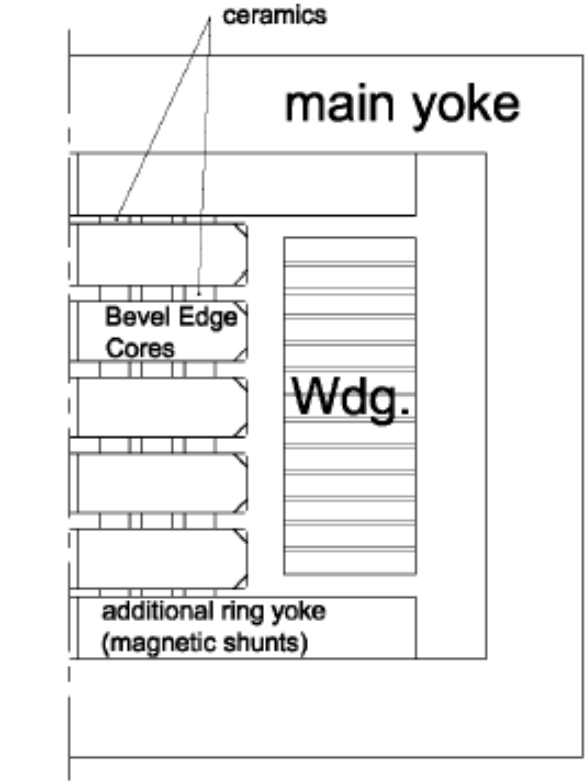
In new advanced designs BEVEL EDGE core packets are used to reduce the EDDY CURRENT LOSSES and SOUND LEVEL



MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

In big powers loss differences are remarkable,particularly in single phase

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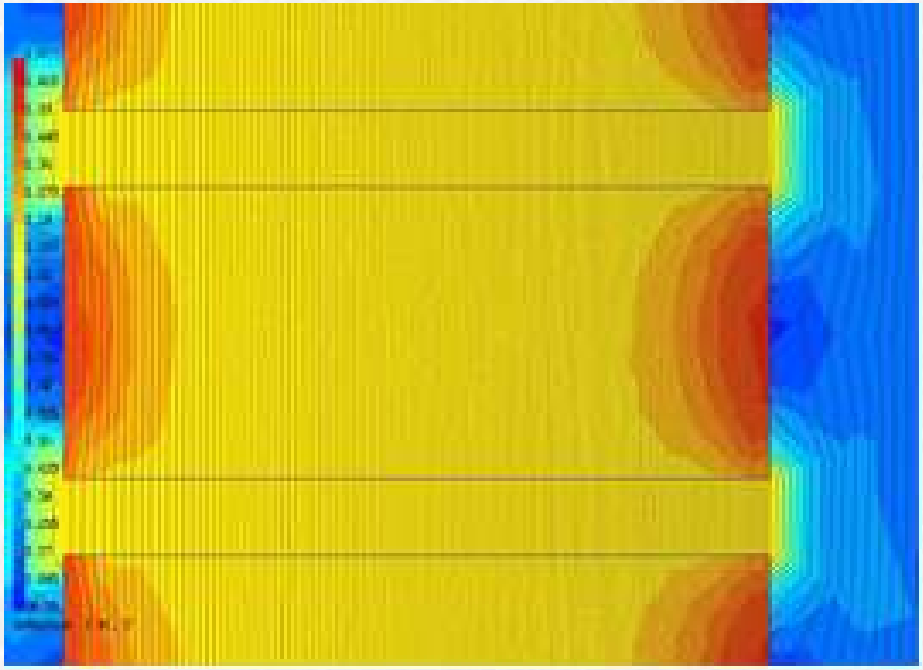
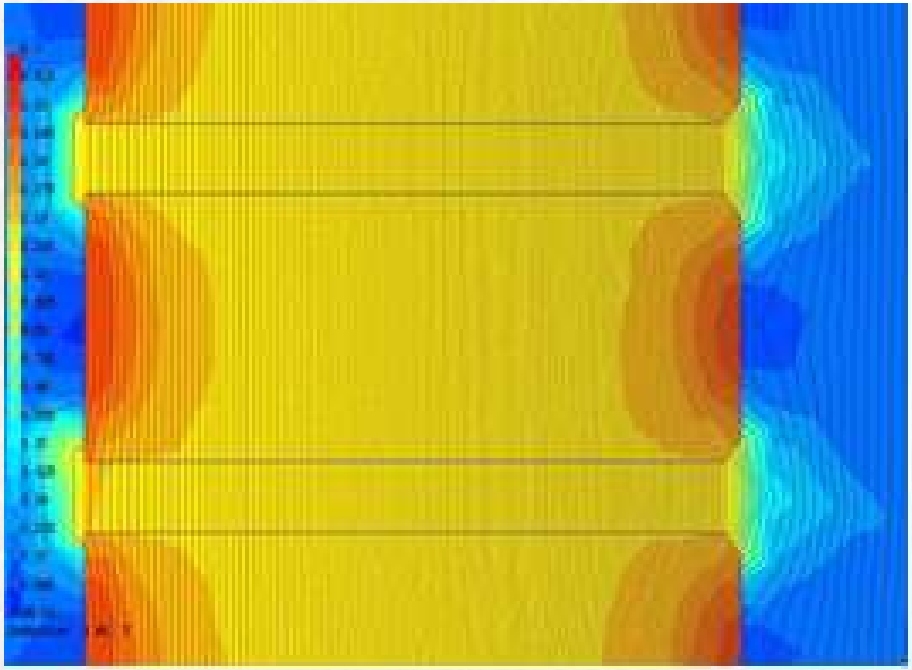
BY BEVELING CORE LIMB PACKETS THE EDDY CURRENT LOSSES ARE REDUCED



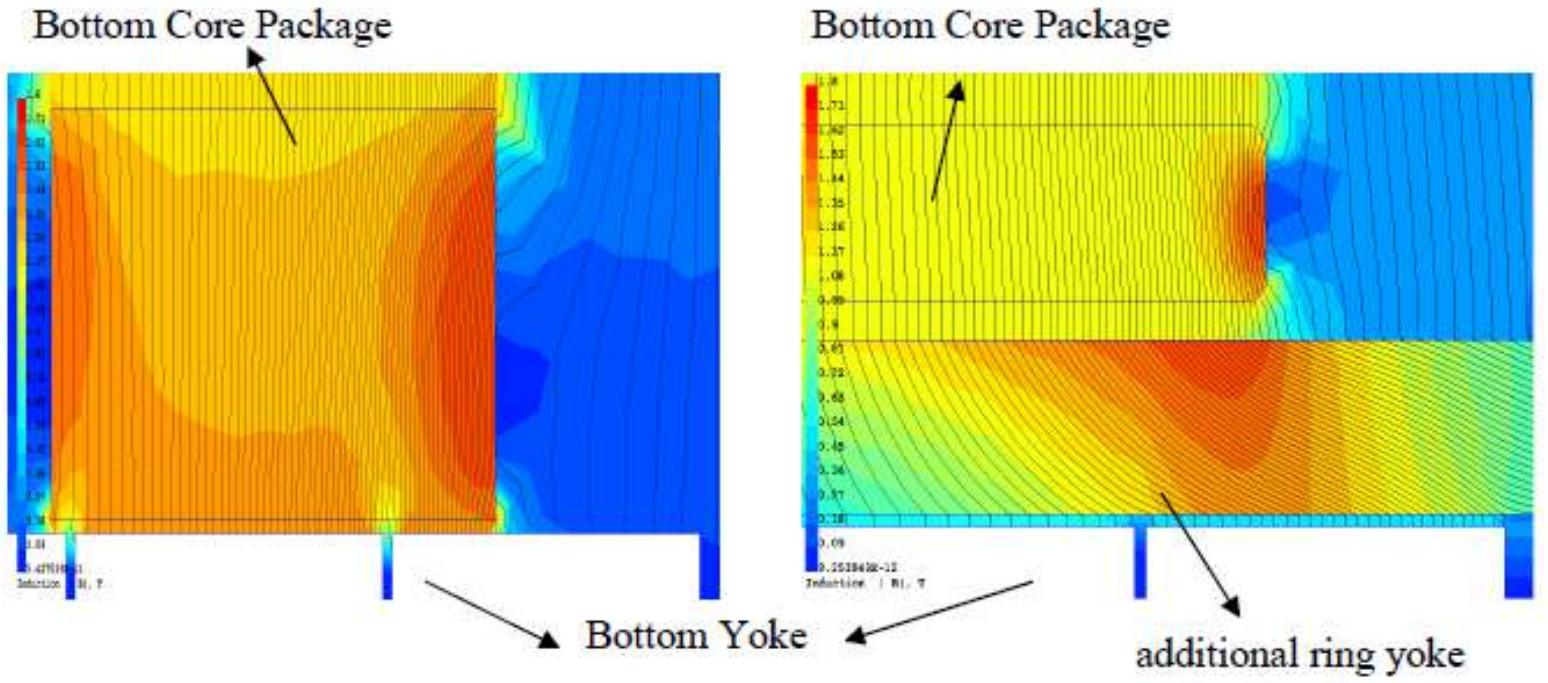
Core Package without Bevel Edge



Core Package with Bevel Edge

Two simulation pictures shows the differences between core packets without and with Bevel Edge

BY USING ADDITIONAL RING YOKE (SHUNTS) THE ADDITIONAL LOSSES ARE REDUCED



Core Package without Bevel Edge

Core Package with Bevel Edge and with Additional ring yoke

Additional Ring yokes (shunts), special flux plates also act as winding press plates. But also provide at top and bottom of winding to collect the leakage flux, thereby minimizing stray losses in tank and eddy current loss, Consequent hot spot at the end discs of winding.

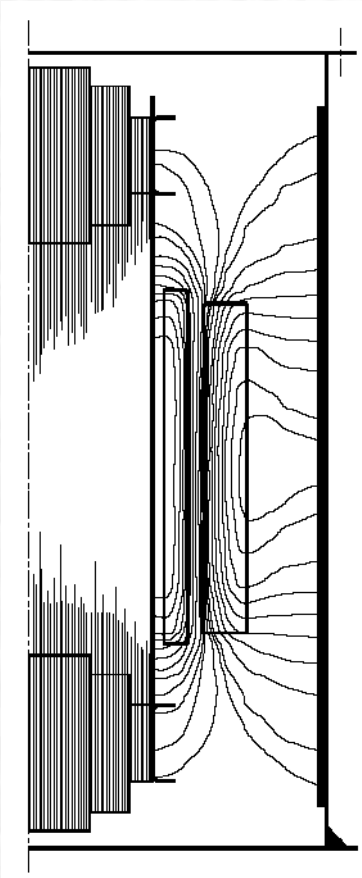
Rectangular additional yokes can not have the same result of additional ring yokes.

2C. TANK- JOKE SHILDINGS FOR TRANSFORMERS & REACTORS

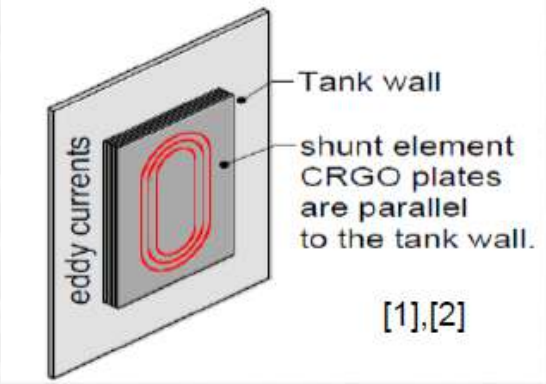
The stray losses due to leakage field cause hot spots in structural components.

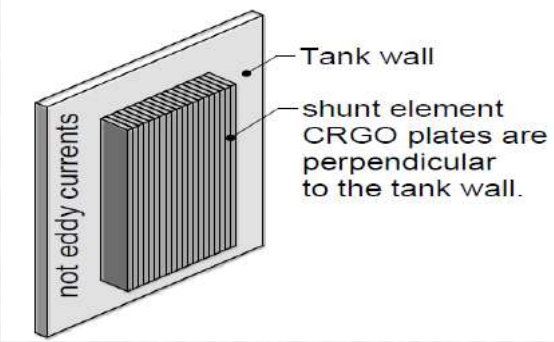
Challenges for state-of-the-art shielding:

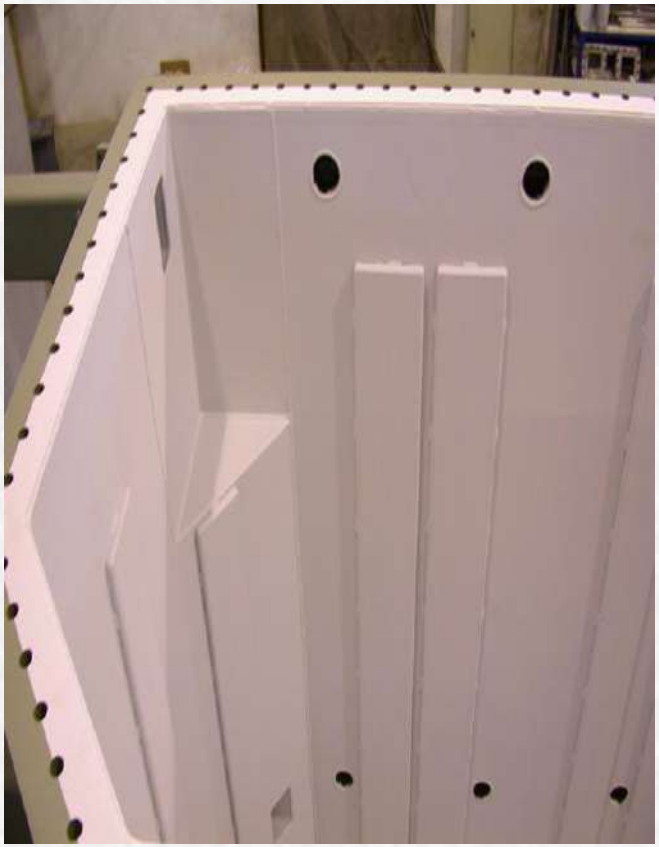
-Length from top yoke to bottom yoke
-Thickness of shunt depends on Flux
-cover at least 70% of windings area
-Distance between 2 shunt elements should be minimum
-Type of shunts edgewise, perpendicular to tank wall, not parallel



MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS







MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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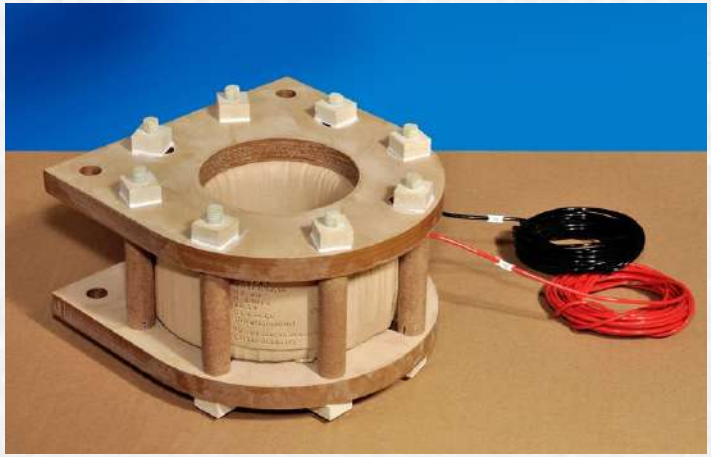
TANK SHUNTS

YOKE SHUNTS

3. CT.FOR BUSHINGS

3A. CT.FOR OIL TYPE TRANSF.BUSHINGS



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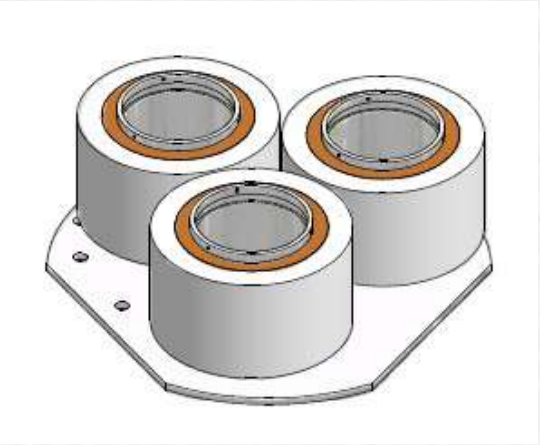
3A. FOR CT.s

EXCITATION CURRENT OF CT's IN 3-PHASE SYSTEMS



The excitation current is important to define CE (composite error) value for P and C protection classes in IEC 60044-1 & IEEE C 57.13 standards. CE value is a critical parameter for these type protection classes. We also provide that **the differences of calculated CE value between each other less than 10%** if it's defined at an inquiry.

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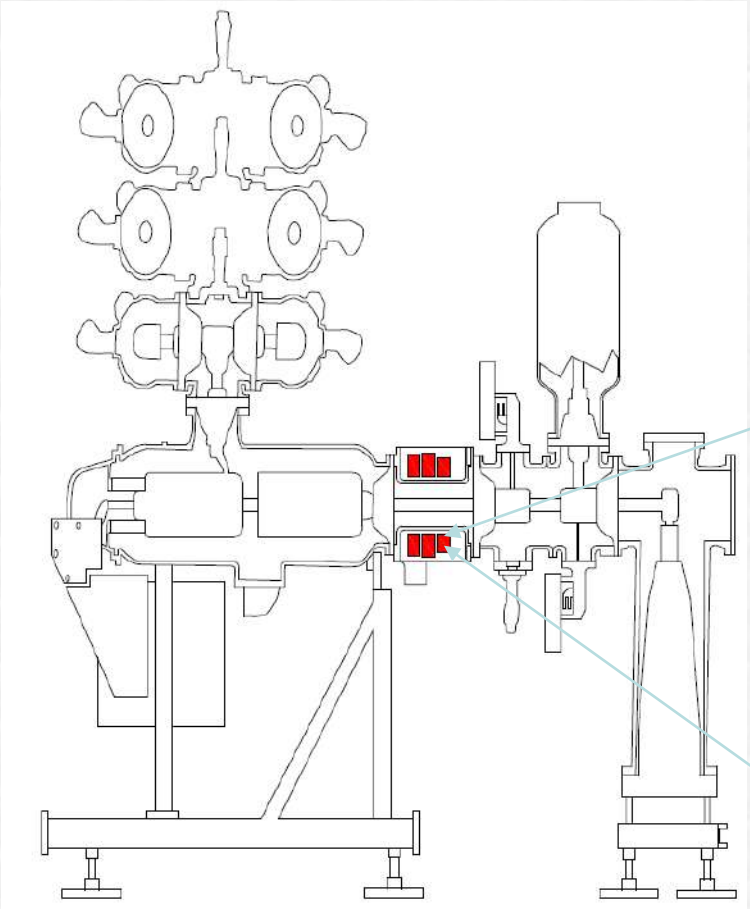
3B. CT. FOR GIS (SF6) TYPE3



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4. QUALTY CONTROL FOR:

4A. INSULATION

4B. MAGNETICS

4C. CT.s

4D. INTERNATIONAL ACCREDITATION

4A. INSULATION

Insulation Laboratory
Test Facilities:

1. Electrical Tests
2. Mechanical Tests
3. Chemical Tests
4. Cellulose & Paper Tests
5. Transformer Oil Tests

Conditions:
Temperature : 23±2°C
Relative Humidity : 50 ±5 %

TÜRKAK
Test
TS EN ISO/IEC 17025
AB-0546-T

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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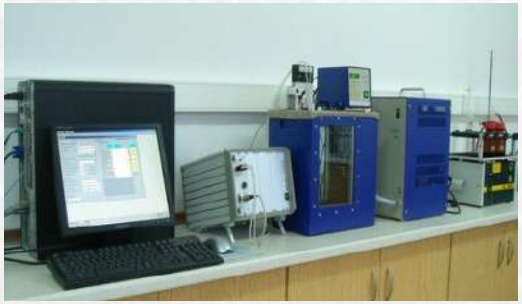
Chemical Tests

- Degree of Polymerization
- Conductivity & pH
- Oil Absorption
- Presence of metallic particles with chemical methods
- Ash Content
- Water Determinations by Karl Fischer Titration
- Moisture Content

Transformer Oil Tests

- Determination of Water by Automatic Coulometric Karl Fischer titration
- Breakdown Voltage
- Dissipation Factor (Tangent Delta) at 90°C
- Acidity (Neutralization value)
- Sludge Content
- Permitivity at 90°C
- Resistivity at 90°C
- Interfacial Tension



TÜRKAK

Test
TS EN ISO/IEC 17025
AB-0546-T

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

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High Voltage Laboratory

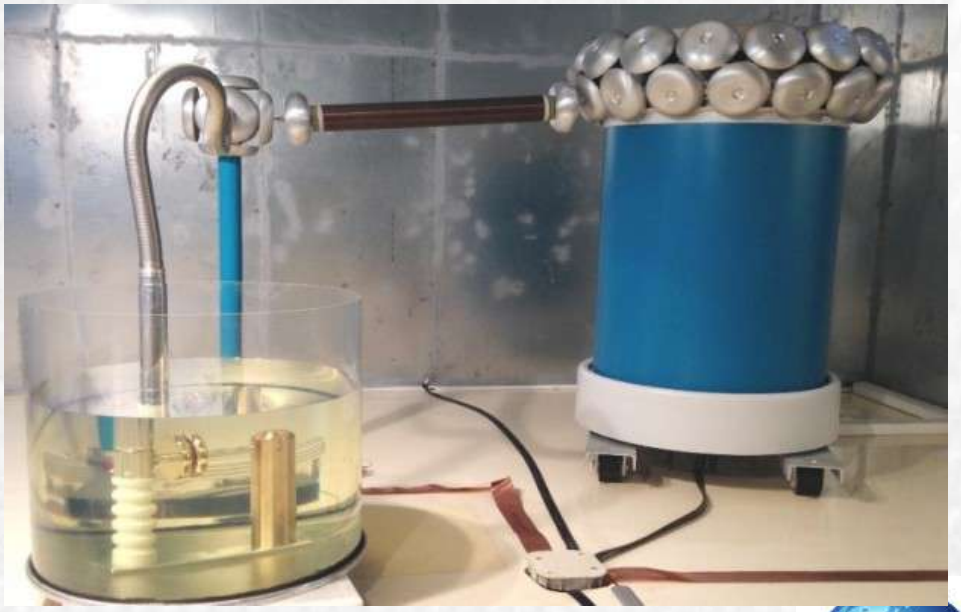
Electrical Tests (Solid Material)

According to IEC 60243
Electrical Strength in Oil
Electrical Strength in Air
Parallel to Lamination
Perpendicular to Lamination

According to IEC 60270
Partial Discharge Test
Inception Voltage >2 pC
Extinction Voltage >2 pC

According to **IEC 60250**
Dissipation Factor (DDF) / Tan δ
Permittivity

TÜRKAK
Test
TS EN ISO/IEC 17025
AB-0546-T



ENPAY Transformer Components

4B. MAGNETICS

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Test
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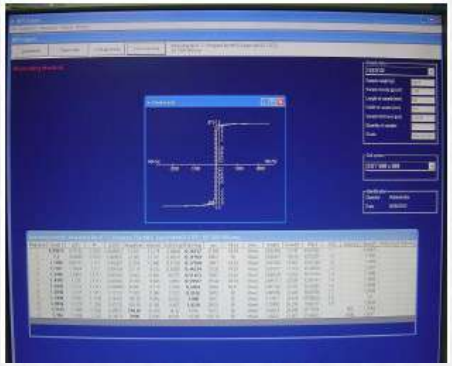
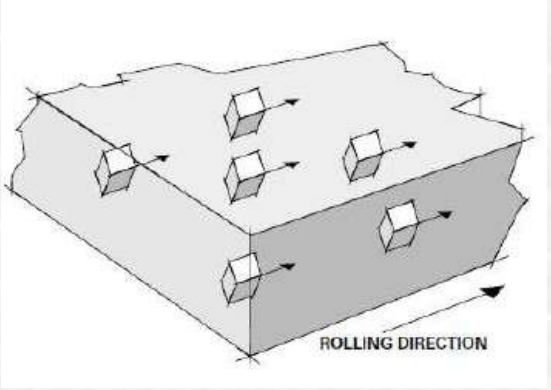
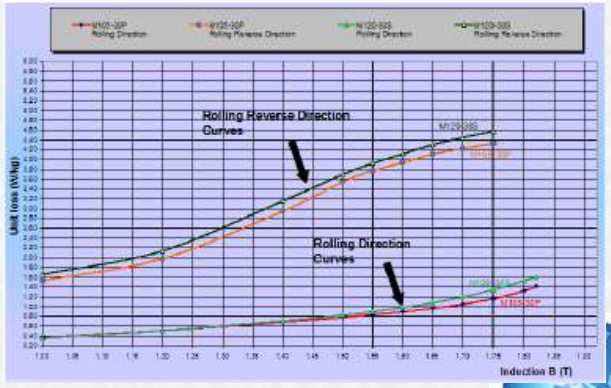
AB-0546-T

Specific total loss (single sheet test)



Specific total loss(Epstein test)





4B. MAGNETICS

Surface Insulation Resistance (Franklin Test) are controlled according to IEC60404-11 Mode A

Surface Insulation Resistance Test Report
By Franklin Test Method

Report No: 120616/01
Date: 16.06.2012
Project: -

Obtain Values of Coils

Surface Insulation Resistance [ohm.cm²]

No	Sample Number	Surface Number	1. Meas.	2. Meas.	3. Meas.	4. Meas.	5. Meas.	Avg.	Avg.
1	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123477 Coil No: A634693AA	Top	14,38	10,79	20,65	9,54	11,02	12,47	
		Bottom	9,11	12,10	6,44	5,99	6,29	7,58	
2	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123477 Coil No: AF634693C	Top	13,33	18,08	32246,78	10,46	12,20	17,16	26,06
		Bottom	34,86	25,80	264,64	116,34	41,94	45,81	
3	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123469 Coil No: A65342250	Top	13,74	16,21	12,80	10,91	9,70	12,36	
		Bottom	4,73	8,91	7,67	12,54	8,83	8,02	
4	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123469 Coil No: BA5342250	Top	3221,78	3221,78	641,78	35,87	41,94	96,56	62,08
		Bottom	399,90	33,30	31,34	36,23	46,01	45,21	
5	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123484 Coil No: CA634104A	Top	24,53	12,78	7,89	15,67	16,89	13,95	
		Bottom	10,35	7,42	6,80	7,29	6,44	7,46	
6	Sheet: M0H0,30 Supplier: XXXXXX PalletNo: 123484 Coil No: A6534104B	Top	103,56	3221,78	641,78	355,11	126,78	226,48	60,15
		Bottom	93,62	44,98	99,81	16,25	19,55	33,53	

Incoming Coil	Measured Coil	Product Type
6	6	LAMINASYON

Revision (Explanations):

Surface Insulation Resistance Test By Franklin Test according to IEC 60404-11 Method-A and Ajdanin Grid DH-4CC-1-100 - Rev02
Test Equipment: Brockhaus Messtechnik -Franklin Sensor: S/N: BM 04 28 01 03680 -Franklin Tester: S/N BM 04 29 02 01479

Calibration Date: 01.02.2012
Next Calibration Date: 01.02.2013

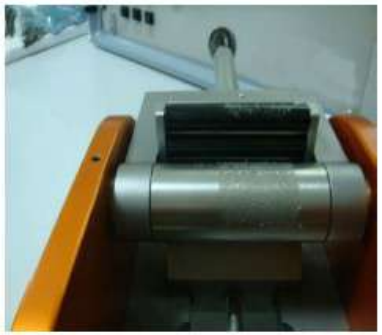
Controlled by O.K

Approved by O.K

4B. MAGNETICS

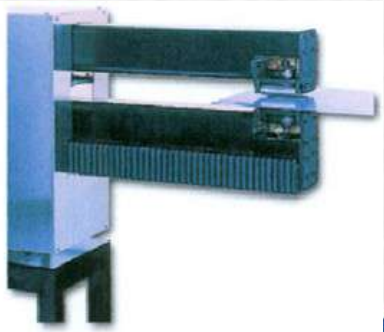
Adhesion test

Adhesion Test are controlled according to IEC60404-12



Online Continious Measuring Surface Condition and Thickness Measuring

Surface Condition are controlled according to IEC60404-8-7 / 6.4

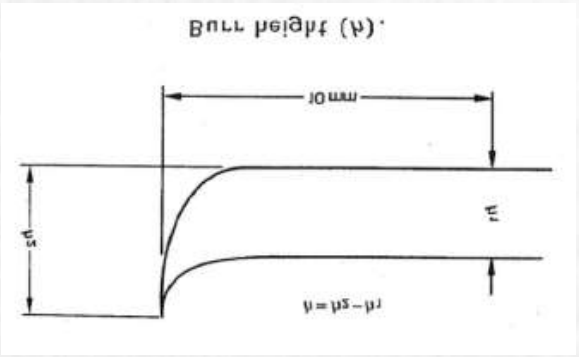


4B. MAGNETICS

Burr height measuring

The measured burr height shall not exceed 0,025 mm according to IEC60404-8-7 and EN10107.

But, the burr height value is applied max. 0.010 mm by ENPAY.



MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

4C. CT.s

4D. INTERNATIONAL ACCREDITATION

TÜRK AKREDİTASYON KURUMU

COPY OF THE ACCREDITATION CERTIFICATE

As a Testing Laboratory,

ENPAY ENDÜSTRİYEL PAZARLAMA VE YATIRIM A.Ş.
Enpay Endüstriyel Pazarlama Ve Yatırım A.ş.
karadenizliler mah. fakülte cad. no:147/A kullar başiskele
41140 KOCAELİ / TÜRKİYE

is accredited in accordance with **TS EN ISO/IEC 17025:2010** within the scope given in Annex following the assessment conducted by **TÜRKAK**.

Accreditation Number : **AB-0546-T**

Accreditation Date : **19 May 2012**

This certificate shall remain in force until **18 May 2016**, subject to continuing compliance with the standard **TS EN ISO/IEC 17025:2010**, related regulations and requirements.

H.İrfan AKSOY
Deputy Secretary General

Annex of the Certificate (Page 1/5)

Accreditation Scope

ENPAY ENDÜSTRİYEL PAZARLAMA VE YATIRIM A.Ş.
Enpay Endüstriyel Pazarlama Ve Yatırım A.ş.

Accreditation Number: AB-0546-T
Revision Number: 00 Date: 19 May 2012

Address: karadenizliler mah. fakülte cad. no:147/A kullar başiskele 41140 KOCAELİ / TÜRKİYE

Phone : 02823495820
Fax : 02823495830
E-Mail : info@enpay.com
Website: www.enpay.com

Tested Materials / Products	Name of Test	Testing Method (National, international standards, in house methods)
Pressboard and Presspaper for Electrical Purposes	Thickness	IEC 60641 - 2 (Clause 5)
	Apparent Density	IEC 60641 - 2 (Clause 6)
	Tensile Strength	IEC 60641 - 2 (Clause 7)
	Elongation	IEC 60641 - 2 (Clause 7)
	Compressibility	IEC 60641 - 2 (Clause 10)
	Shrinkage	IEC 60641 - 2 (Clause 11)
	Pyboric Resistance	IEC 60641 - 2 (Clause 12)
	Moisture Content	IEC 60641 - 2 (Clause 13)
	Ash Content	IEC 60641 - 2 (Clause 14)
	Conductivity of aqueous extract	IEC 60641 - 2 (Clause 15)
	pH of aqueous extract	IEC 60641 - 2 (Clause 16)
	Oil Absorption	IEC 60641 - 2 (Clause 17)
	Electric Strength	IEC 60641 - 2 (Clause 20)
Laminated Pressboard	Thickness	IEC 60763 - 2 (Clause 5.1)
	Flexural Strength	IEC 60763 - 2 (Clause 6.1)
	Modulus of Elasticity in Flexure	IEC 60763 - 2 (Clause 6
	Compressibility	IEC 60763 - 2 (Clause 7

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

ENPAY Transformer Components

Annex of the Certificate (Page 2/5)

Accreditation Scope

ENPAY ENDÜSTRİYEL PAZARLAMA VE YATIRIM A.Ş.
Enpay Endüstriyel Pazarlama Ve Yatırım A.Ş.

Accreditation Number: AB-0546-T
Revision Number: 00 Date: 19 May 2012

Tested Materials / Products	Name of Test	Testing Method (National, International standards, in house methods)
(Laminated Pressboard continued)	Electric Strength	IEC 60763 - 2 (Clause 8)
	Internal Ply Strength	IEC 60763 - 2 (Clause 9)
	Apparent Density	IEC 60763 - 2 (Clause 10)
	Moisture Content	IEC 60763 - 2 (Clause 11)
	Shrinkage	IEC 60763 - 2 (Clause 12)
	Oil Absorption	IEC 60763 - 2 (Clause 13)
	Ash Content	IEC 60763 - 2 (Clause 14)
	Contamination of Liquid Dielectrics	IEC 60763 - 2 (Clause 15)
	Conductivity of Aqueous Extract	IEC 60763 - 2 (Clause 16)
	pH of Aqueous Extract	IEC 60763 - 2 (Clause 17)
Cellulosic Electrically Insulating Materials	Measurement of Average Viscometric Degree of Polymerization	IEC 60450
	The Determination of The Permittivity and Dielectric Dissipation Factor	IEC 60250
	Partial Discharge Measurements	IEC 60270
	Electrical Strength (Tests at power frequencies)	IEC 60243-1
Paper and board	Paper and board – Determination of tensile properties	ISO 1924-2
	Determination of moisture content of a lot – Oven-drying method	ISO 287
Paper, board and pulps	Determination of residue (ash) on ignition at 900 degrees C	ISO 2144
Insulating Liquids	Determination of Water by Automatic Coulometric Karl Fischer Titration	IEC 60814

Annex of the Certificate (Page 3/5)

Accreditation Scope

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Accreditation Number: AB-0546-T
Revision Number: 00 Date: 19 May 2012

Tested Materials / Products	Name of Test	Testing Method (National, International standards, in house methods)
(Insulating Liquids continued)	Determination of The Breakdown Voltage	IEC 60156
	Measurement of Relative Permittivity, Dielectric Dissipation Factor (tan δ) and D.C. Resistivity	IEC 60247
	Determination of Acidity	IEC 62021-1
	Sludge Formation	IEC 61125 (Clause - 1.9.1)
	Interfacial Tension of Oil Against Water by the Ring Method	ASTM D971-99a
Current Transformer	Verification of terminal markings	IEC 60044-1
	Power frequency withstand test on secondary winding and between sections	IEC 60044-1
	Inter-turn overvoltage test	IEC 60044-1
	Determination of errors	IEC 60044-1
	Routine test for accuracy of measuring current transformers	IEC 60044-1
	Instrument security factor	IEC 60044-1
	Type and routine tests for current error and phase displacement of protective current transformers	IEC 60044-1
	Routine test for composite error	IEC 60044-1
	Determination of remenance factor (Kr)	IEC 60044-1
	Determination of secondary loop time constant (Ts)	IEC 60044-1
	Determination of secondary winding resistance (Rct)	IEC 60044-1
	Routine tests for class PX protective current transformers	IEC 60044-1

MV-UHV (AC-DC) POWER TRANSFORMER COMPONENTS

ENPAY Transformer Components

Annex of the Certificate (Page 4/5)

Accreditation Scope

ENPAY ENDÜSTRİYEL PAZARLAMA VE YATIRIM A.Ş.
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Accreditation Number: AB-0546-T
Revision Number: 00 Date: 19 May 2012

Tested Materials / Products	Name of Test	Testing Method (National, International standards, in house methods)
(Current Transformer continued)	Rated knee point E.M.F. (Ek) and maximum exciting current (Ie)	IEC 60044-1
	Secondary winding resistance (Rct)	IEC 60044-1
	Turns ratio error	IEC 60044-1
	Insulation tests	IEC 60044-1
	Inter-turn insulation tests	IEC 60044-1
	Turns ratio error	IEC 60044-6
	Steady state ratio error and phase displacement	IEC 60044-6
	Determination of secondary winding resistance (Rct)	IEC 60044-6
	Determination of secondary excitation characteristic	IEC 60044-6
	Determination of remenance factor (Kr)	IEC 60044-6
	Calculation of secondary loop time constant (Ts)	IEC 60044-6
	Applied voltage dielectric test between windings and between windings and ground	IEEE ANSI C57.13
	Induced voltage test	IEEE ANSI C57.13
	Accuracy test	IEEE ANSI C57.13
	Polarity test	IEEE ANSI C57.13
	Excitation test	IEEE ANSI C57.13
	Ratio correction curve	IEEE ANSI C57.13
	DC resistance	IEEE ANSI C57.13

Annex of the Certificate (Page 5/5)

Accreditation Scope

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Accreditation Number: AB-0546-T
Revision Number: 00 Date: 19 May 2012

Tested Materials / Products	Name of Test	Testing Method (National, International standards, in house methods)
Magnetic Materials	Measurement of the Magnetic Properties of Electrical Steel Sheet and Strip by Means of an EPSTEIN Frame	IEC 60404-2

End of Scope

H.İrfan AKSOY
Deputy Secretary General

Thank You
For Your Attention