WEBINAR

2024 Winter Webinar Round-Up

Plus, Live Panel Discussion

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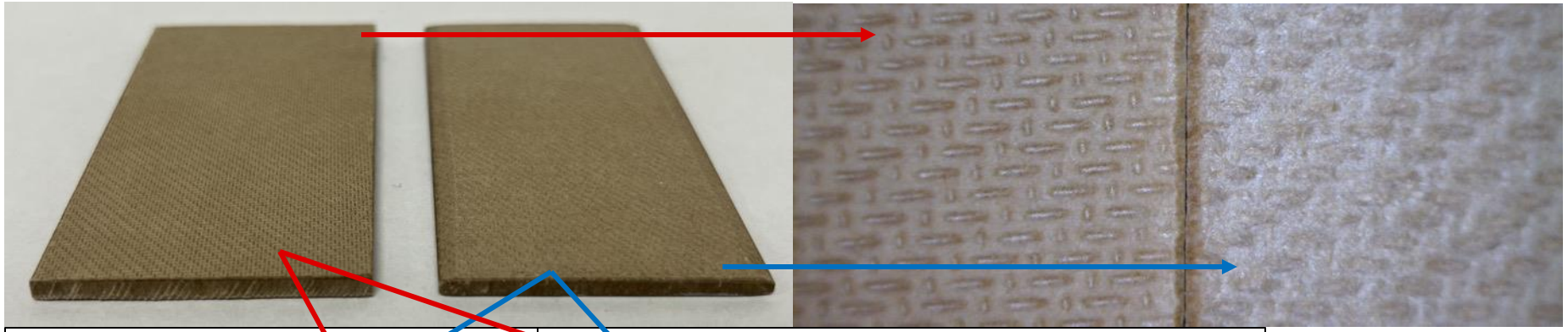
INSULATION DESIGN CONCEPTS

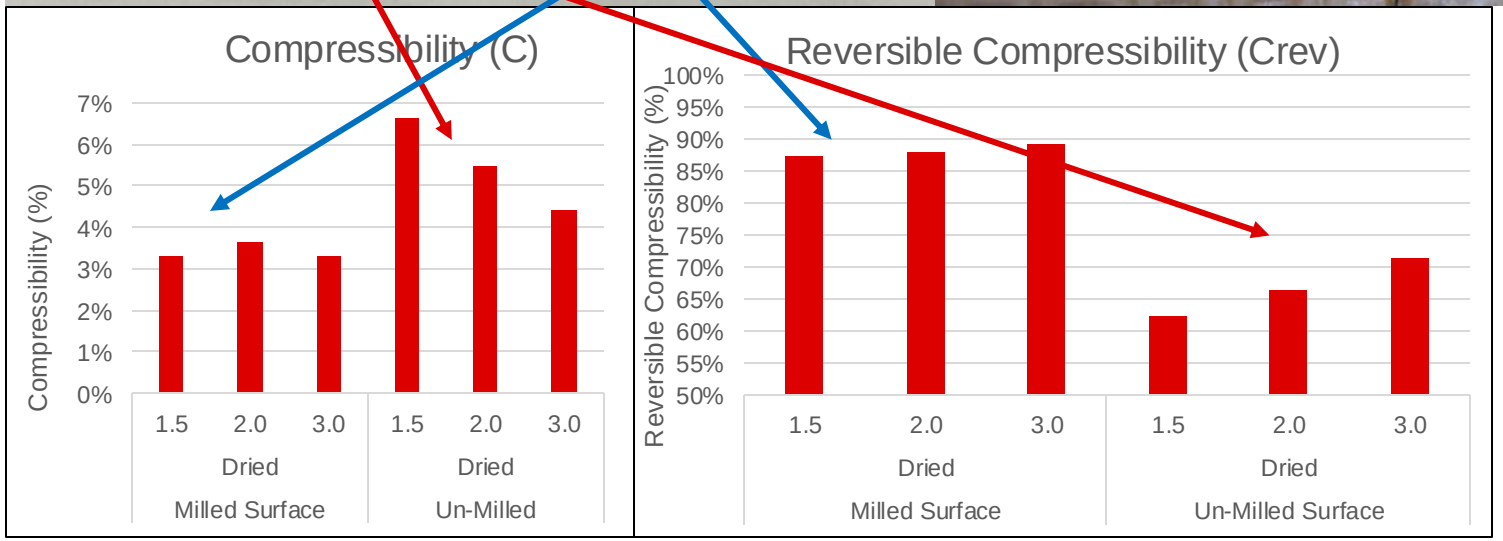
INSULATION CONCEPTS TO OPTIMIZE THE DESIGN OF LIQUID-FILLED TRANSFORMERS

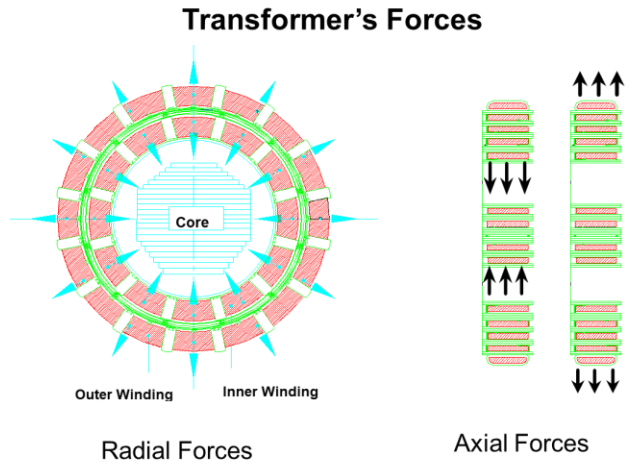
OPTIMIZED SHORT CIRCUIT RESILIENCE THROUGH PROPER COIL SIZE CONTROL

Un-milled surface has higher compressibility and lower reversible compressibility than milled

Un-milled surface is largely dependent on thickness



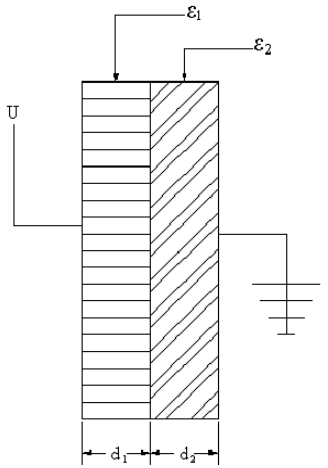




INSULATION CONCEPTS TO OPTIMIZE THE DESIGN OF LIQUID-FILLED TRANSFORMERS

OPTIMIZED STRESS DISTRIBUTION BY UNDERSTANDING THE CURVES AND MATERIALS

- Dielectric stress distributes inversely proportional to the material permittivity



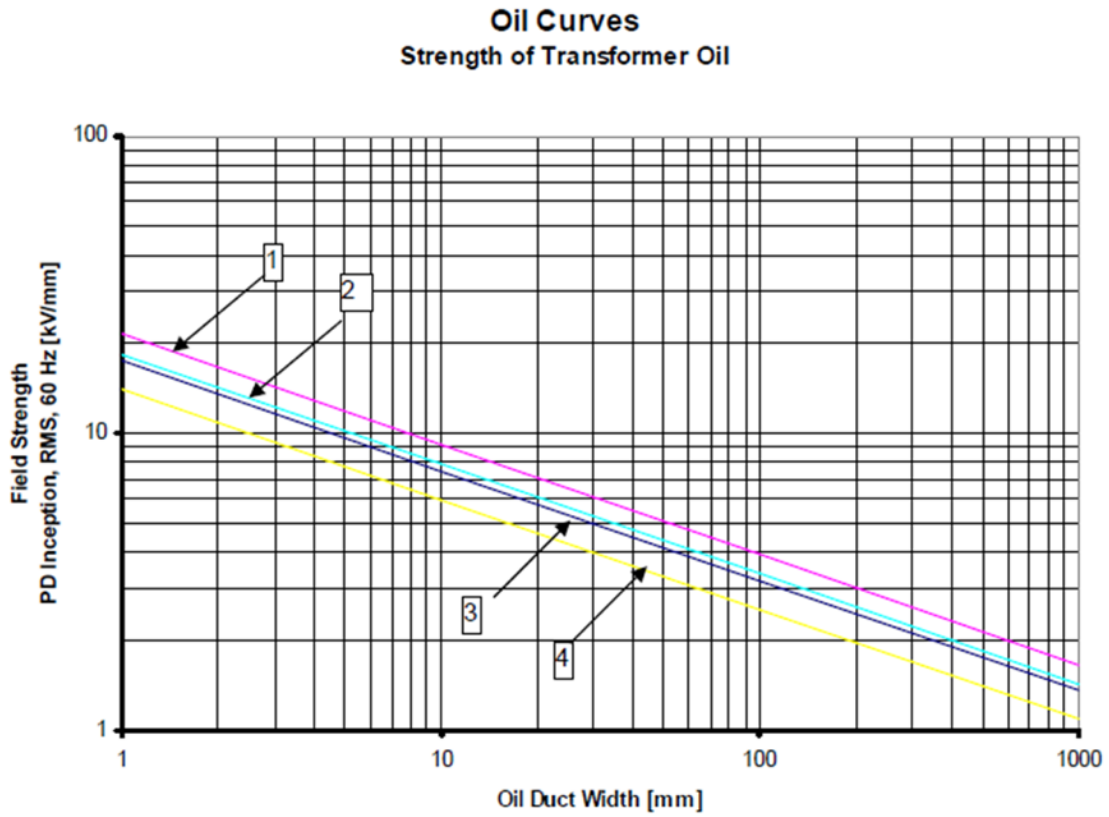
ε_1=permittivity mat. 1
ε_2=permittivity mat. 2
$Z=(d_1/\varepsilon_1) + (d_2/\varepsilon_2)$

$E_1 = U/(\varepsilon_1 * Z)$

$E_2 = U/(\varepsilon_2 * Z)$

U= Applied Voltage
E_1= Stress in material 1
E_2= Stress in material 2

HD PB & MO	**LD PB & MO**
$\varepsilon_1 = \varepsilon_{PB} = 4.6$	$\varepsilon_1 = \varepsilon_{PB} = 3.8$
U=100kV	U=100kV
$\varepsilon_2 = \varepsilon_{oil} = 2.2$	$\varepsilon_2 = \varepsilon_{oil} = 2.2$
$d_1 = d_2$=5mm	$d_1 = d_2$=5mm
$E_1 = E_{PB}$= 6.5 kV/mm	**$E_1 = E_{PB}$= 7.3 kV/mm**
$E_2 = E_{oil}$=13.5kV/mm	**$E_2 = E_{oil}$=12.7kV/mm**



The strength of the dielectric liquids decrease as the length of the gap increases
The inverse is also true!

ACCELERATED AGING TEST - A DETERMINATION OF TRANSFOMERBOARD THERMAL CLASS

ACCELERATED AGING TEST & TRANSFORMERBOARD THERMAL CLASS

SEALED TUBE ACCELERATE AGING

Industry practice and International Standards recognize the utilization of non thermally upgraded pressboard with thermally upgraded paper as a 120 class insulation system for mineral oil immersed transformers

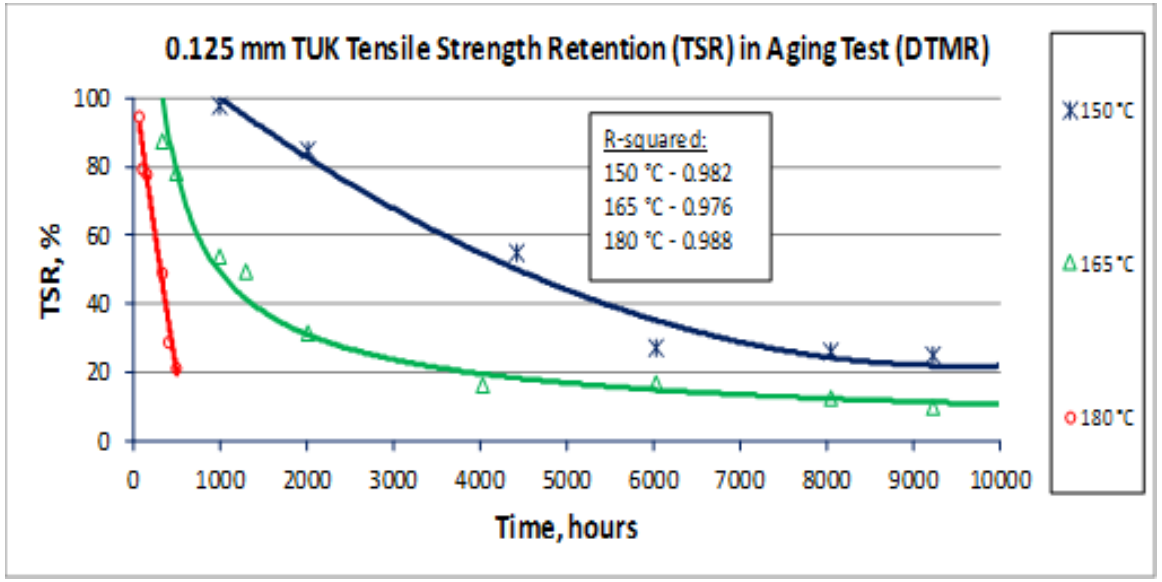
IEEE C57.100 provides guidance for such an evaluation with the Sealed Tube Accelerated Aging Test (STAAT)

<u>Industry Proven System – Per Table B.1</u>

- Test Program:
  - Standard PTMR test with T4 and TUK
  - Standard DTMR test with Hi-Val and TUK
- Three Temperatures
  - 150, 165, & 180 °C
- Multiple aging periods per temperature
  - PTMR – 8
  - DTMR – 6
- Candidate system was the Transformerboard

Table B.1—Sealed tube materials ratios

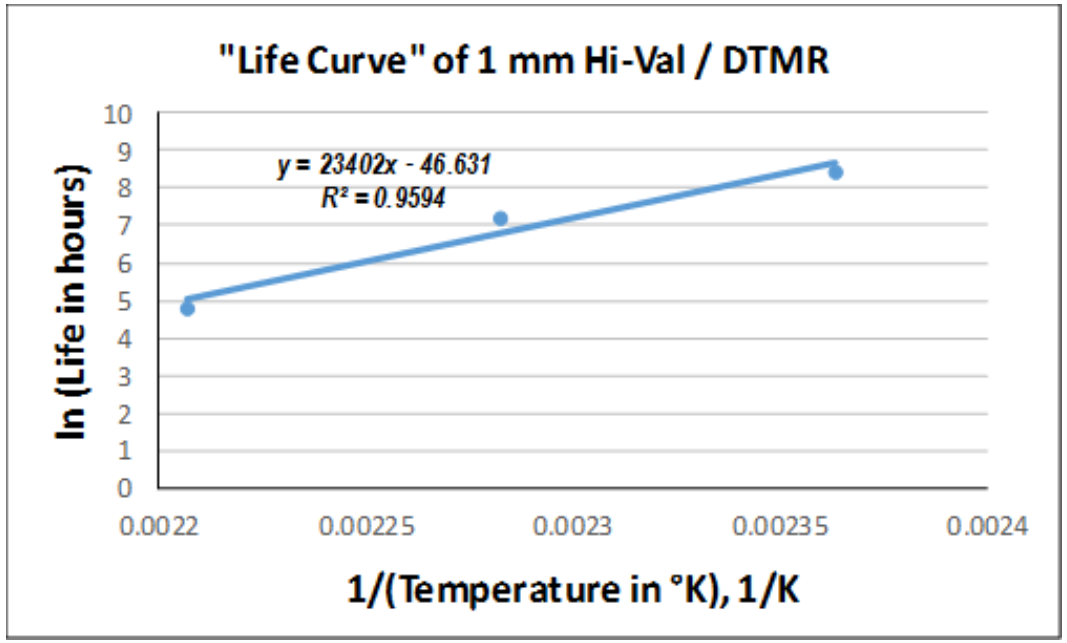
	Transformer type	
Material	Power	Distribution
Insulating liquid	200 cm^3	200 cm^3
0.05 to 0.10 mm conductor insulation	6.4 cm^3	
0.13 to 0.38 mm layer insulation		11.2 cm^3
1.00 to 3.00 mm low-density pressboard		1.2 cm^3
2.00 to 8.00 mm high-density pressboard	16.4 cm^3	
Ratio—liquid to solid	8.8 to 1	16.3 to 1



ACCELERATED AGING TEST & TRANSFORMERBOARD THERMAL CLASS

CONCLUSIONS

- **Can we determine the thermal class of Transformerboard using an industry recognized test procedure? YES!**
- For the first time in the industry the thermal class of Transformerboard (both LD and HD) was confirmed to be 120 °C through sealed tube accelerated aging testing.
- Thermal class definitions cannot be determined on an individual material.
- The thermal class is on the entire insulation system
  - Thermally upgraded Kraft paper
  - Non-thermally upgraded Transformerboard
  - Mineral oil

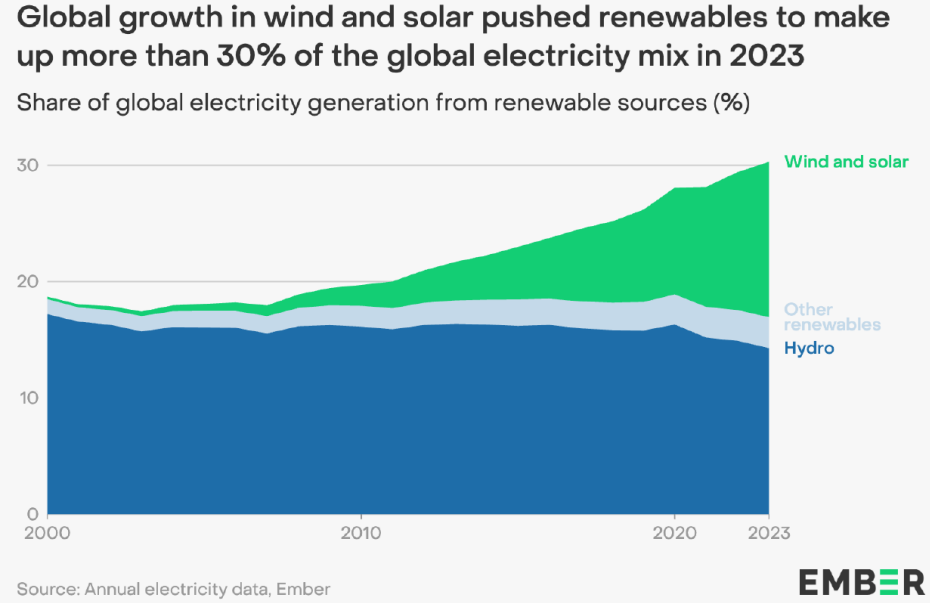


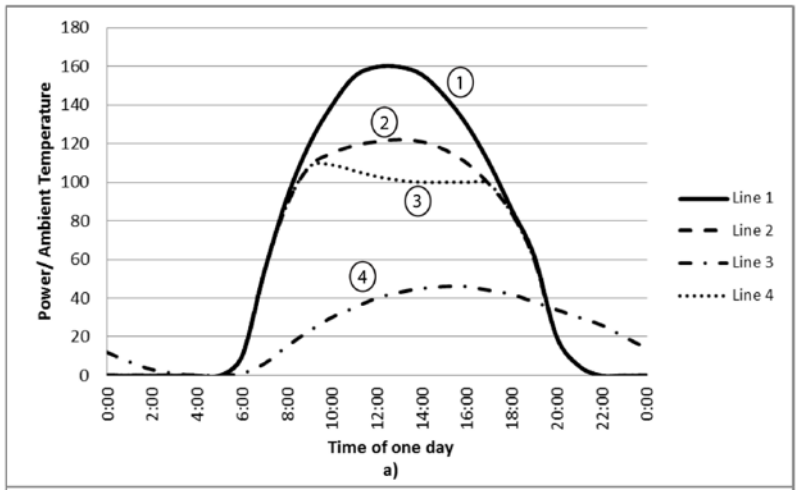
Thermal Index Results (°C)				
Test	**Material**	**Method 1**	**Method 2**	**Method 3**
DTMR	1 mm Hi-Val	125.3	127.3	115.4
	0.13 mm TUK	-	123.8	116.7
PTMR	2 mm T4	129.4	116.2	113.0
	0.08 mm TUK	-	110.8	105.0

OPTIMIZED INSULATION FOR RENEWABLE ENERGY TRANSFORMERS

RENEWABLE ENERGY GENERATION GROWTH

HAS BECOME A MAJOR ENERGY SOURCE





IEEE C57.159™: Load profile of a solar power generation inverter connected transformer; (3) = Transformer active load (% of nominal nameplate power)

1. Intermittent / variable character of renewable power sources
2. Un-utilized excessive transformer capacity (leading to excessive capital investments and increased site footprint)
3. Sites can be at locations with high ambient temperatures (shorter life span, reduced reliability)
4. Unfavorable power generation / power loss ratio (no-load losses continue with zero or reduced power generation)

EU Green Deal impact assessment

- Share of electricity in energy use will rise from 23 % in 2015, to ~30 % in 2030, and ~50 % in 2050
- Electricity distribution networks' peak load capacities will have to be reinforced substantially (heat pumps & EVs)

Sustainable peak load transformers provide a solution

- Can be applied in all cases where the difference between peak and average demand is proportionately high
- Typical case for distribution networks and renewable energy generation transformers

They can technically be loaded continuously at peak load kVA

- Will not affect transformer reliability or lifetime
- Use of peak load capacity will only be limited in time to keep annual load losses below the desired value

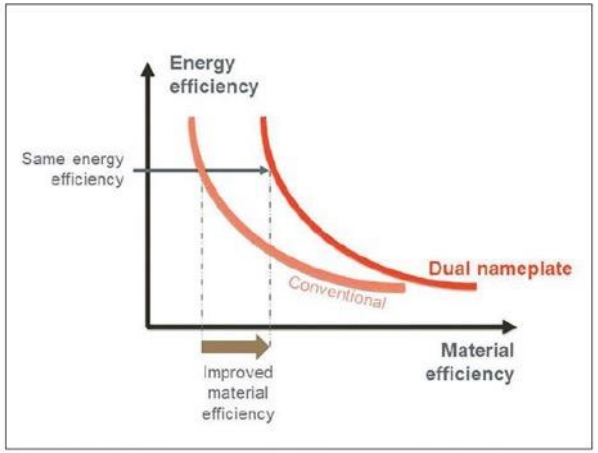
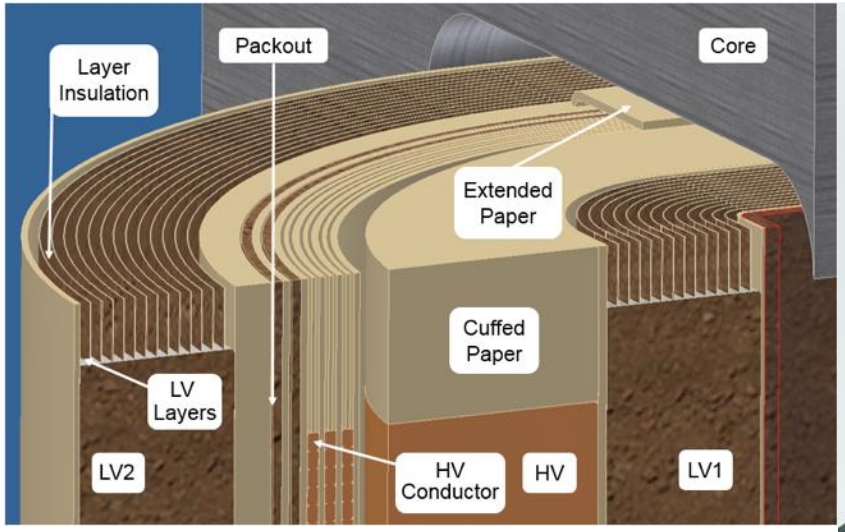
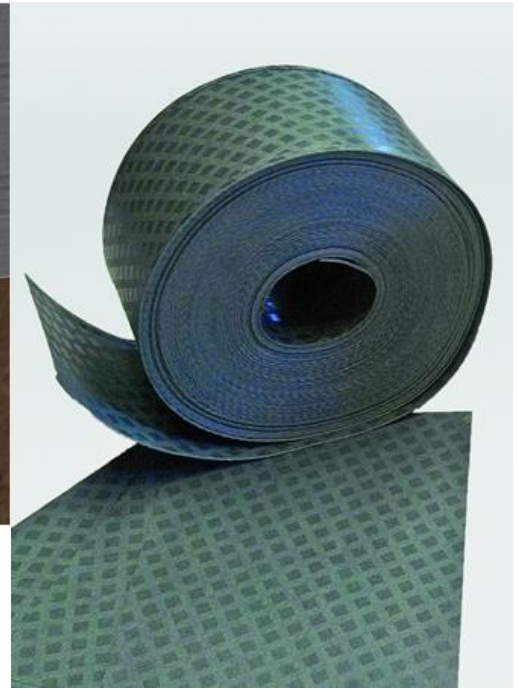


Figure 1. Energy efficiency versus material efficiency: a conventional transformer compared with a sustainable peak load transformer ("Dual nameplate")

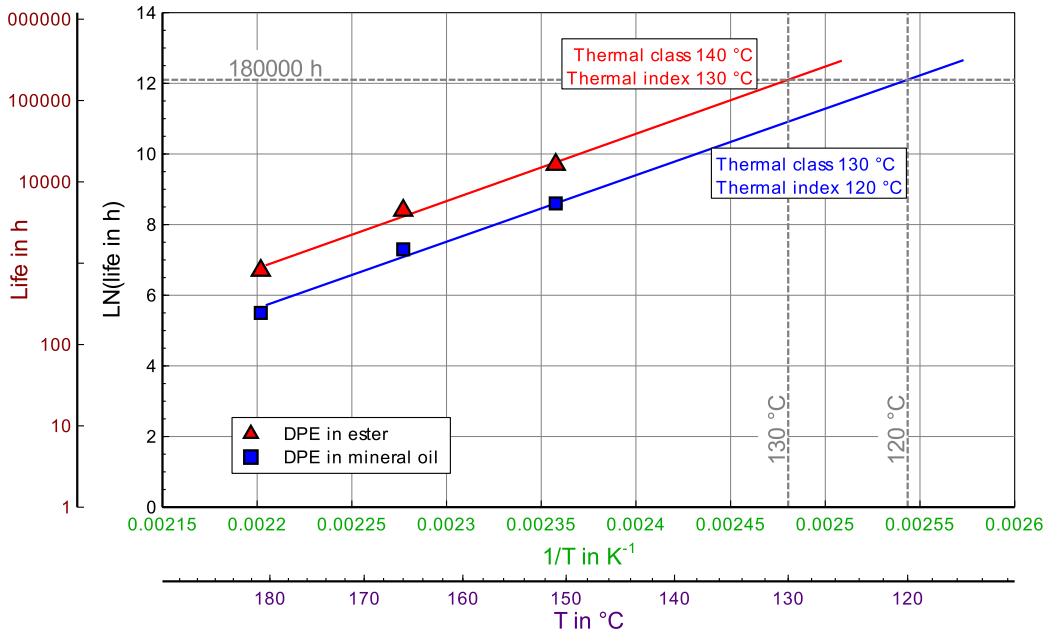
LAYER-TYPE TRANSFORMER FOR RENEWABLE APPLICATIONS

DESIGN AND APPLICATION WITH DIAMOND PATTERN ENHANCED (DPE) PAPERS





- **DPE dries up to 30% faster than other cellulose papers**
- **DPE impregnates up to 30% faster both in mineral oil & ester liquids**



Option 1: Same size (rated capacity) transformer with about 20% higher overload capability (no to minimal design changes)

Option 2: Smaller (rated capacity) transformer with equivalent overload capability, but smaller in size, weight, cost, and no-load losses (higher efficiency)

SUSTAINABILITY OF TRANSFORMER INSULATION

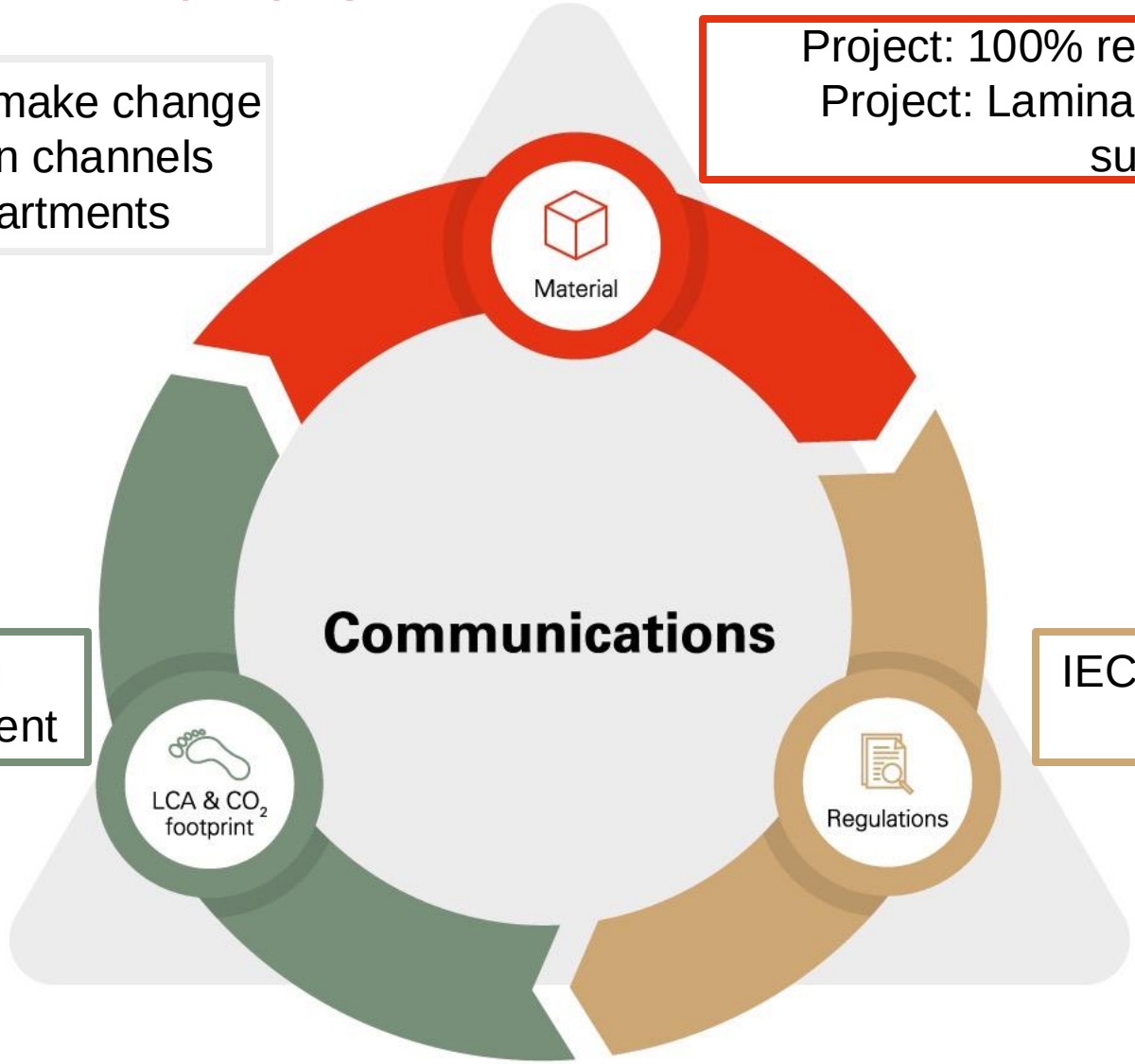
Circular economy practices & responsible use of raw materials

SUSTAINABILITY OF TRANSFORMER INSULATION

CIRCULAR ECONOMY PRACTICES

Improve the will & trust to make change
Establish communication channels
for innovation departments

Project: 100% recycled Transformerboard
Project: Laminated board with improved sustainability



Improved packaging
Supply chain commitment

IEC specifications
Ecovadis

SUSTAINABILITY OF TRANSFORMER INSULATION

RESPONSIBLE USE OF RAW MATERIALS

- We aim to use only FSC-certified wood
- We aim to recycle as many fibers as possible

- Lake of Zurich used as a natural water reservoir
- No additives used
- Water is cleaned and checked before being released back into the lake

- Energy usage maximized for sustainable performance

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THANK YOU!

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