Paris Session 2022

Thermal class of alternative oil/paper systems

SC A2 PS2
Q2.5: What is the experience of using alternative transformer technologies at higher temperatures?

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Reminder

- **Standard IEC 60076-14 (Annex C) ***
  - Thermal class of Kraft (or TUP) can be increased in presence of Natural ester
    - **From 105°C to 120°C** (or from 120°C to 140°C)
    - Trans-esterification reaction
  - **Natural ester** is a Tri-ester (IEC 62770) naturally obtained from seeds whereas **Synthetic ester** is a Tetra-ester (IEC 61099) derived from chemicals

Table C.2 – Comparison of ageing results

	Constant a	Temperature T °C	Thermal index	Thermal class
IEEE mineral oil/thermally upgraded paper	$9{,}80 \times 10^{-18}$	110,0	110	120
Natural ester liquid/thermally upgraded paper	$7{,}25 \times 10^{-17}$	130,6	130	140
IEEE mineral oil/kraft paper	$2{,}00 \times 10^{-18}$	95,1	95	105
Natural ester liquid/kraft paper	$1{,}06 \times 10^{-17}$	110,8	110	120

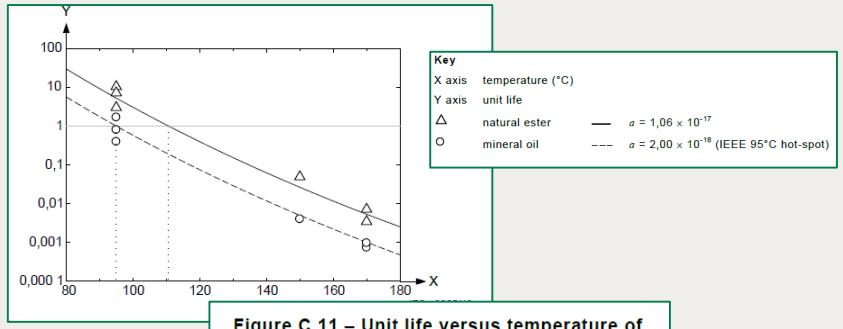


Figure C.11 – Unit life versus temperature of kraft paper ageing data (least squares fit)

➢ **<u>Question</u>: Is it applicable for synthetic ester (Tetra-ester / IEC 61099)?**

* *"Liquid immersed power transformers using HT insulation materials"*

Aim & Test conditions

- **Thermal ageing & Comparative study between different oil/paper systems at laboratory scale**
- **Based on IEC TS 62332-2 ***
  - 2 different temperatures & 4 sampling periods
  - Insulating oil + Kraft paper (105°C) + Enamelled Cu

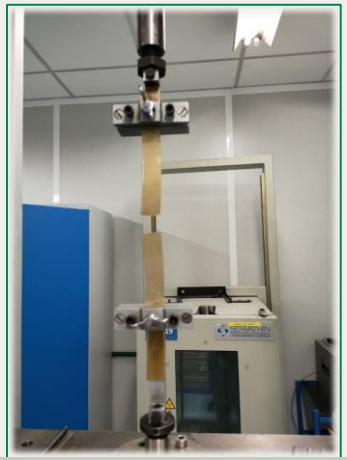
	Ageing time 1 3000 h	Ageing time 2 625 h
Ageing Temperature for Natural ester system	145 °C	160 °C
Ageing Temperature For other systems	130 °C	145 °C

- End of life criteria defined at **40% of initial Tensile Strength** of Kraft paper
- Determination of the **Thermal Index** by Arrhenius law at a time of **20 000h**

Tested materials

Oil type	Standard	Thermal class of liquid	Thermal class of oil/paper (IEC 60076-14)
Natural ester	IEC 62770	130 °C	120 °C
Synthetic ester	IEC 61099	130 °C	?
Mineral oil 1	IEC 60296 (A)	105 °C	105 °C
Mineral oil 2	IEC 60296 (B)	105 °C	105 °C
Biodegradable oil 1	IEC 60296 (A)	105 °C	Should be 105 °C
Biodegradable oil 2	IEC 60296 (A)	105 °C	Should be 105 °C

Glass vessel sealed under vacuum containing oil, paper and copper



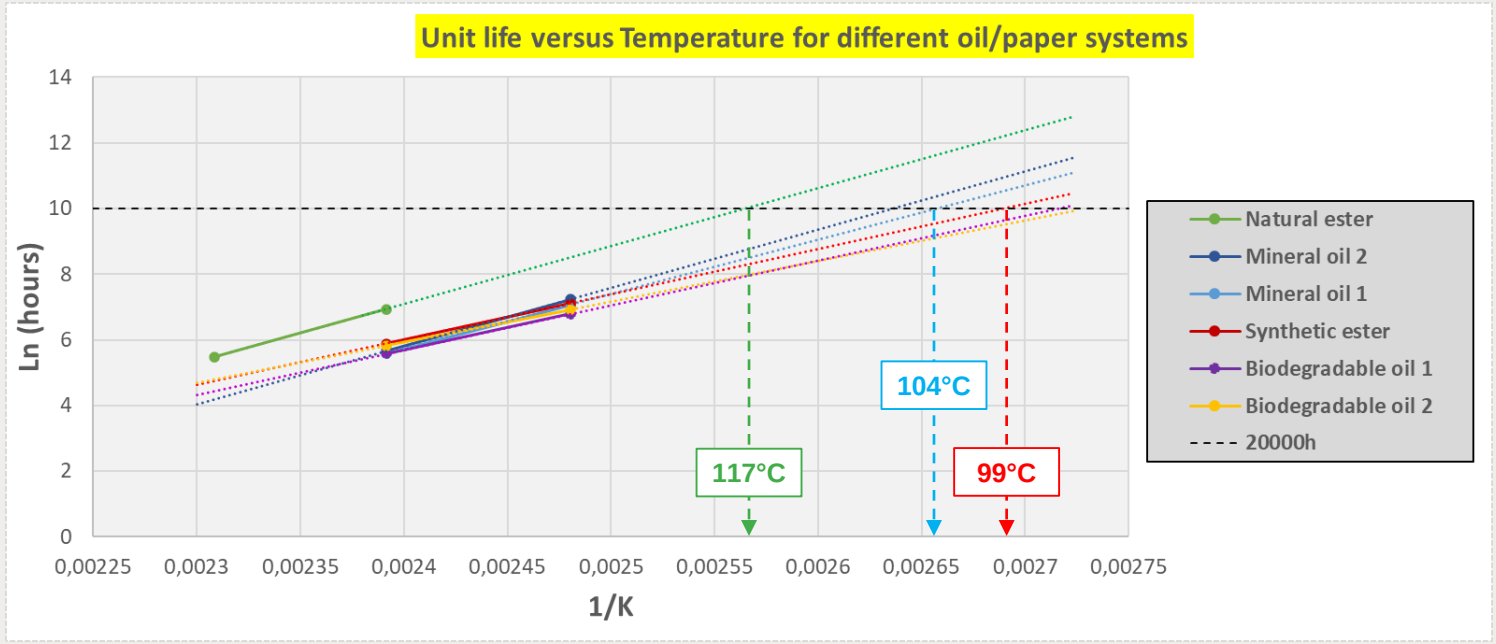
Tensile Strength test on Kraft paper

** "Electrical insulation (EIS) – Thermal evaluation of combined liquid and solid components"*

Test results

- From experimental data, **calculated thermal index** is better for Natural ester than other systems

- Synthetic ester cannot be considered as the natural ester regarding the thermal class oil/paper



Oil type	Thermal index from laboratory study	Thermal class of oil/paper given in IEC 60076-14
Natural ester	**117 °C**	120°C
Synthetic ester	**99 °C**	-
Mineral oil 1	**104 °C**	105°C
Mineral oil 2	**107 °C**	105°C
Biodegradable oil 1	**96 °C**	- (*)
Biodegradable oil 2	**94 °C**	- (*)

(*): should be 105°C as IEC 60296 oil

Conclusion & Next steps

• From these investigations, Synthetic ester (Tetra-ester / IEC 61099) cannot be considered as the Natural ester (Tri-ester / IEC 62770) regarding the thermal class of the oil/paper system

• Biodegradable oils (IEC 60296) seem to have slightly lower protection than conventional mineral oils on the cellulosic insulation

• **Presented results are currently based on 2 points and a 3rd point is under process to finalize and validate the study**