NAME : **PERRIER**
COUNTRY : **France**
REGISTRATION NUMBER : **5303**

GROUP REF. : **A2**
PREF. SUBJECT : **PS2**
QUESTION N° : **Q2.5**

Thermal class of alternative oil/paper systems

Introduction

Ester liquids are more and more used because of their higher fire safety (K class liquid) and their better biodegradability versus conventional mineral oil. The standard IEC 60076-14 (Annex C) [1] indicates that the thermal class of the Kraft paper and the thermally upgraded paper (TUP) can be increased in presence of Natural ester. This improvement is from 105°C to 120°C for the Kraft paper and from 120°C to 140°C for the TUP. As a reminder, Natural ester is a tri-ester (IEC 62770) naturally synthesized from seeds whereas Synthetic ester is tetra-ester derived from chemicals. **The question is: can we use this improvement for synthetic ester as well?**

To answer to this question, a comparative study regarding the thermal ageing of different oil/paper systems was launched at laboratory scale.

Test conditions

The thermal ageing study is based on the IEC TS 62332-2 [2] with ageing at 2 different temperatures as indicated in the below table 1. Different oils (see table 2) are aged in presence of Kraft paper and enameled copper in glass vessel sealed under vacuum. For each ageing, there are 4 sampling periods.

As the end of life of a transformer is driven by the end of life of the cellulosic insulation, the end of life criteria was defined with the tensile strength (TS) of the paper. The ageing temperatures and the value of 40% of initial tensile strength as end of life criteria were selected based on preliminary investigations (short ageing at high temperatures of 160°C and 175°C). From these experimental data, the thermal index by Arrhenius law was defined at a time of 20 000 h.

	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

Table 1: Ageing temperatures

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

Table 2: Tested materials

Figure 1: Glass vessel under vacuum containing oil, paper and copper

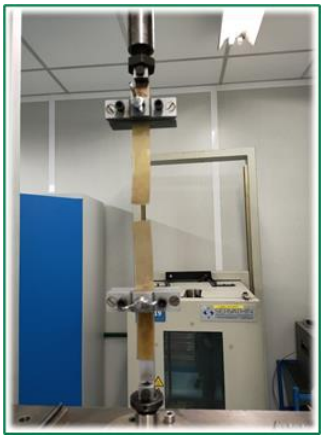

Figure 2: Tensile strength test on Kraft paper

Test results

From the experimental data (figure 3 and table 3) and as comparative study, calculated thermal index is better for natural ester than other systems. For natural esters and minerals oils, results are relatively close from the thermal class defined in the IEC 60076-14, whereas results on synthetic ester and biodegradable oils are slightly lower than conventional mineral oil.

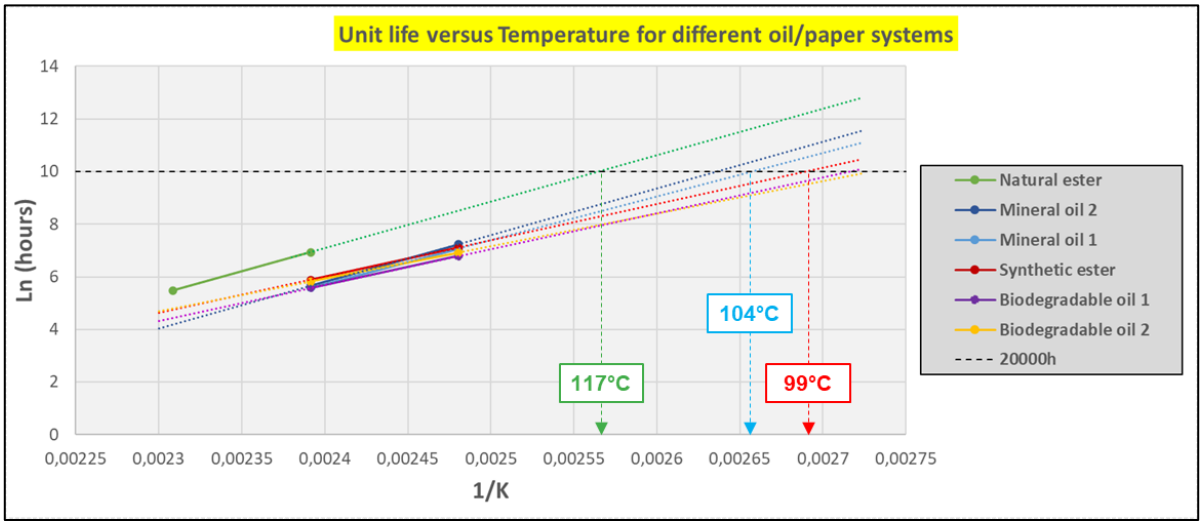

Figure 3: Unit life versus temperature for different oil/paper systems

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**	- (*)

Table 3: Thermal index calculation for all systems

**: should be 105°C as considered as IEC 60296 oil*

Conclusion

From these investigations, it can be underlined that:

- Synthetic ester (IEC 61099) cannot be considered as the natural ester (IEC 62770) regarding the thermal class of 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 two points (figure 3) and a 3rd point is under process to finalize and validate the study.

[1] IEC 60076-14:2013 “Liquid immersed transformers using high temperature insulation materials”.

[2] IEC TS 62332-2:2014 “Electrical insulation systems (EIS) – Thermal evaluation of combined liquid and solid components – Part 2 : Simplified test”.