Moisture equilibrium charts

For effective condition monitoring of natural ester fluid-filled green transformers

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CLEAN GRID GREEN TRANSFORMER
POWER TRANSFORMERS

"Green" transformers, which use eco-friendly biodegradable vegetable oil insulation, need moisture equilibrium charts for their monitoring and diagnosis. In-depth experiments have been carried out to produce and validate such charts. This is an important step toward longer service life with effective condition monitoring.

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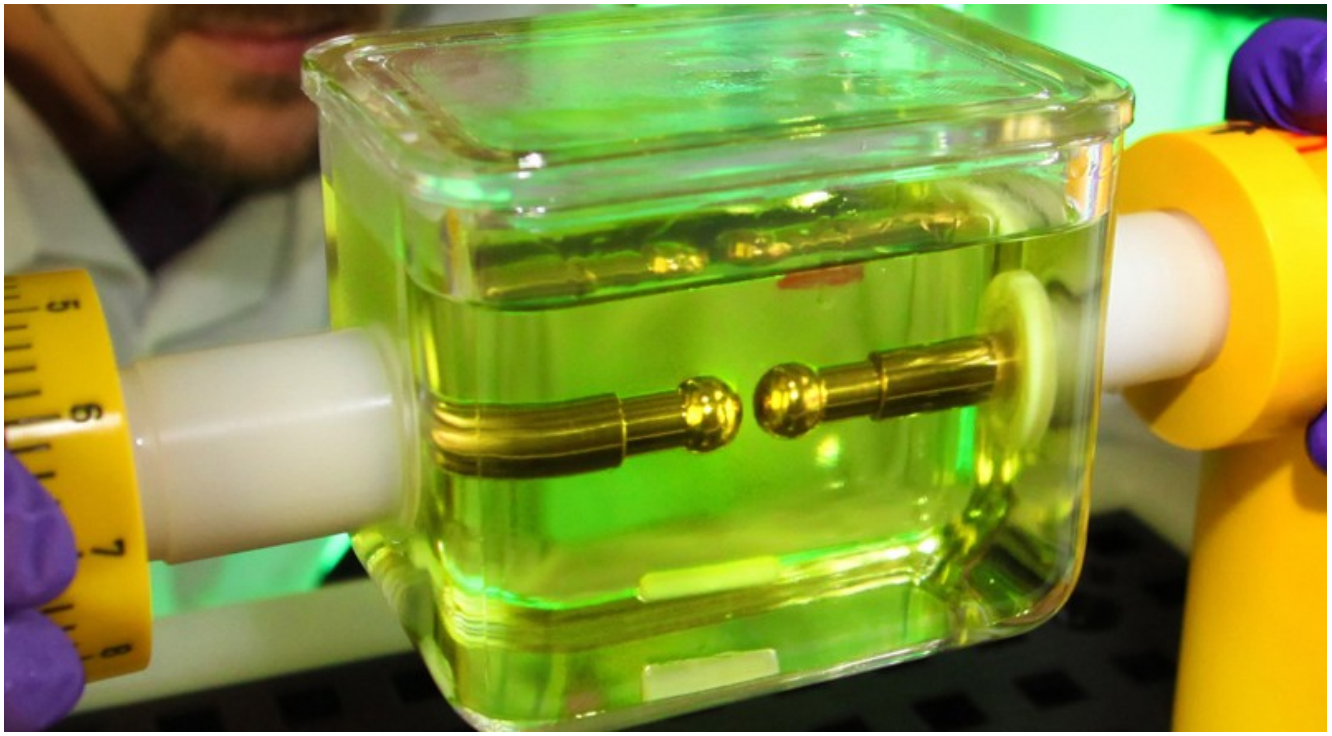

Green transformers, a sustainable and environment-friendly range of power transformers (PTs), are gaining in popularity. Demand is steadily growing. They are used as simple distribution transformers or sophisticated high voltage power transformers. They owe their development to the introduction of innovative technologies such as biodegradable insulating liquids combined with a hermetically sealed design, as well as noise reduction, etc.

Green Energy Transformer

Natural esters, or "vegetable oils," offer several advantages over mineral oils: they are biologically degradable and thus do not affect groundwater. They are less flammable and they have a protective effect on transformer insulation, notably because they are less sensitive to humidity (higher water solubility), which means that they can absorb more water. Power transformer insulation consists of a composite system made of cellulosic materials (mainly paper and pressboard) impregnated with insulating liquid (mainly mineral or ester oils). Since the cellulose insulation is more hygroscopic than the oil, it contains most of the water, which can constitute several percentages by weight of the total mass. "Excessive moisture in cellulosic materials can affect the life of transformers by significantly reducing both dielectric and mechanical strengths," explains Christophe Perrier, R&D Project Manager at GE Grid Solutions in Villeurbanne, France. "This is why the in-service evaluation of moisture in cellulosic insulation is a very important aspect of the condition assessment of power transformers—whether using mineral or vegetable oil." Since it is not possible to remove cellulose samples from the active

windings of a transformer in operation, indirect measurements were developed by assessment of the oil humidity and the use of experimentally derived moisture equilibrium charts. “Knowledge of the moisture content distribution within the various materials (oil, paper, pressboard), which are dependent on diffusion and absorption-desorption processes, is valuable in insulation diagnosis and manufacturing dry-out processes,” says Perrier.

Charts for natural ester oil

"While there are large volumes of information for mineral oils, pertinent charts for natural fluids are lacking. This is a limiting factor to their implementation in high voltage power transformers,” Perrier points out. For instance, it is generally not known in the existing charts if the equilibrium curves were obtained from experiments using paper and pressboard insulation in mass ratios corresponding to actual ratios used in transformers, or how the water is distributed between the paper and pressboard insulation. To improve the relevance of these charts, GE Grid Solutions developed moisture equilibrium curves for standard Kraft paper and pressboard immersed in natural ester insulating oil. Experiments were also carried out with mineral oil to compare and validate the results with regard to the previous data.

A valuable tool for power utilities

These curves, dubbed “Perrier-Lukic moisture equilibrium curves” (see figures 1 to 3), led to several key findings.

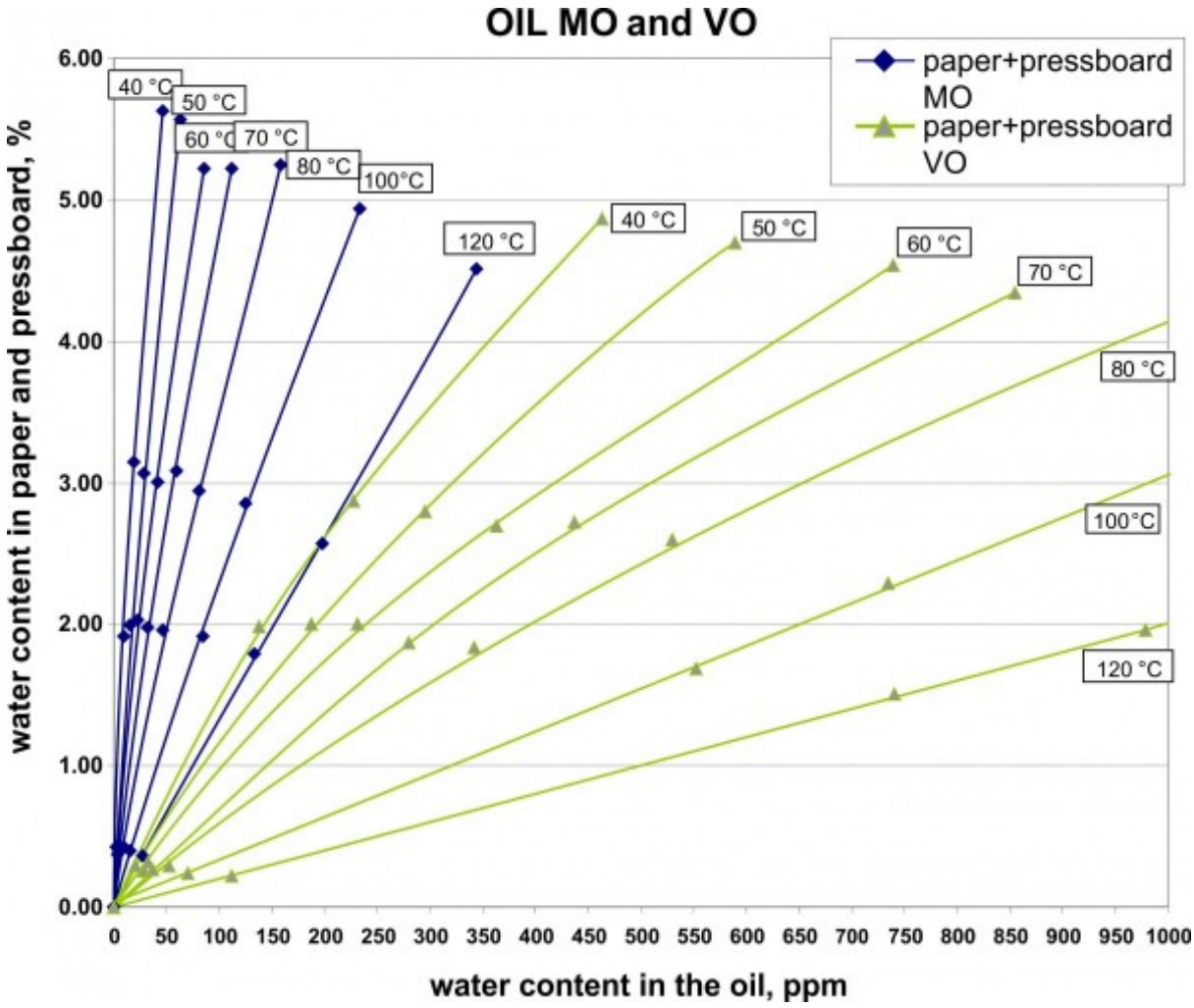

Fig. 1 – Perrier-Lukic equilibrium curves for paper + pressboard together in mineral oil (MO) and vegetable oil (VO)

Due to the higher solubility of moisture in natural ester compared to mineral oil, the moisture equilibrium curves are significantly moved on the right hand side toward the natural ester oil curves (figure 1). Therefore, for the same moisture content in the cellulosic materials, the expected water content in natural ester oil is significantly higher than in mineral oil. For example, for an equilibrium of 60 °C, and 3% water in cellulosic insulation, water content in natural ester oil is around 10 times higher than in mineral oil.

Separate equilibrium curves for paper and pressboard in both oil types are also presented in figures 2 and 3. Distribution of humidity in mineral oil between both types of cellulosic materials is relatively similar, whereas uneven distribution, i.e., lower water content in pressboard and higher water content in paper, was obtained in ester oil. The contributing factors for such behavior in pressboard impregnated with natural ester are

undergoing further investigations.

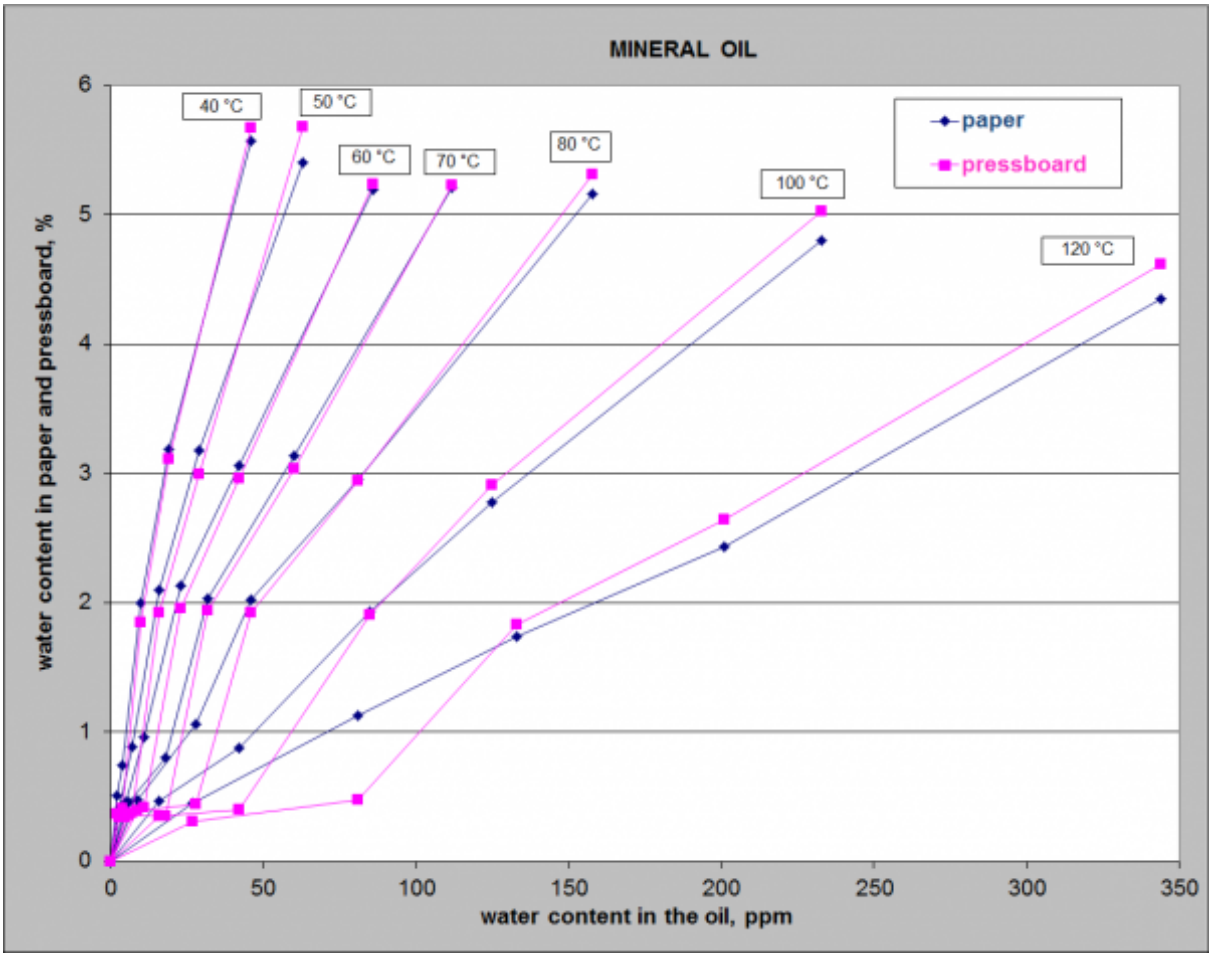

Fig. 2 –Perrier-Lukic equilibrium curves for paper and pressboard in mineral oil.

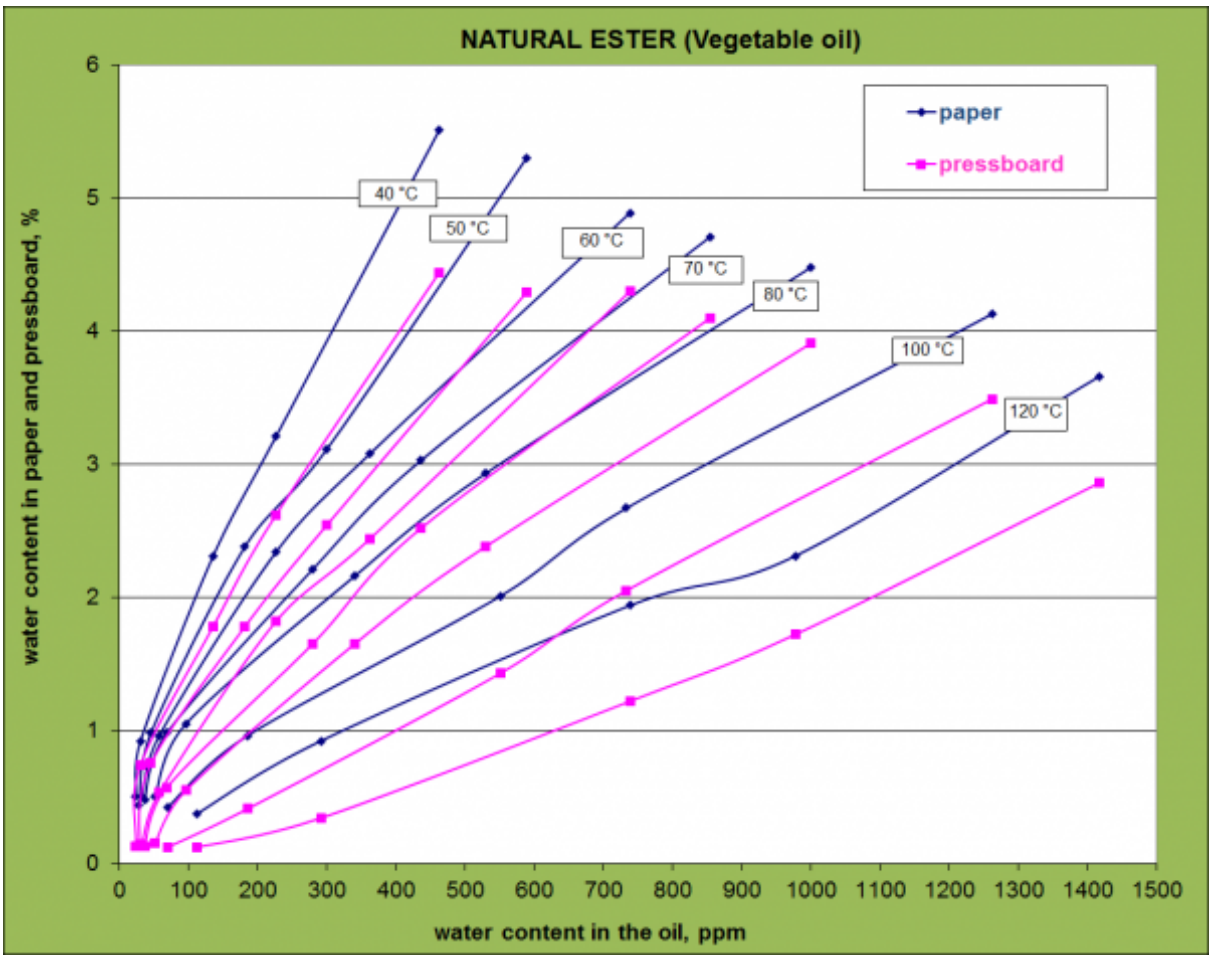

Fig. 3 –Perrier-Lukic equilibrium curves for paper and pressboard in natural ester oil

Nonetheless, the establishment of these complete moisture equilibrium charts for natural ester fluid insulation represents a significant contribution to the development and application of green transformers, "starting with the possibility of checking and ensuring manufacturing quality at the power transformer manufacturing stage. Above all, they provide power utility operators with an efficient tool to monitor and control transformer insulation and increase its lifetime," Perrier concludes.

Transformer insulation: the many benefits of natural esters

Extracted from rapeseed, soya or sunflower, natural ester oils have better thermal class than mineral oil (130 °C compared to 105 °C). Another advantage of ester liquids is their higher water solubility (20 times higher than mineral oil), which is why water content in solid insulation, e.g., insulation barriers as well as paper insulation, is minimized. Vegetable oils have further benefits: they are biodegradable, non-toxic, non-hazardous in the case of fresh water contamination, and they give better fire safety

(higher flash and fire points). Moreover, thanks to their high environmental safety, an additional oil bund under the transformer can be dispensed with, resulting in reduced investment and life-cycle costs for the operator.

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