



NYTRO® THE NEW
BIO 300X BIO-BASED
ALTERNATIVE
FROM NYNAS

NYTRO® BIO 300X

is a bio-based hydrocarbon which has the look and feel of a great mineral insulating oil, and yet it provides a sustainable and environmentally sound solution without compromising performance.

Is NYTRO® BIO 300X a Mineral Oil or an Ester?

NYTRO® BIO 300X is neither a mineral oil nor is it an ester – It is a bio-based hydrocarbon which is readily biodegradable and of ultra-low viscosity. What this means in practical terms is that it has the look and feel of a great mineral insulating oil and yet it provides a sustainable and environmentally sound solution without compromising performance. It has the best of both worlds. Furthermore, natural esters have significant disadvantages; namely, poor oxidation stability, high viscosity and inferior dielectric properties in many conditions [1-5] – these all mean in practice the re-designing of a transformer, which usually costs more than one filled with mineral insulating oil. NYTRO® BIO 300X has excellent oxidation stability, low viscosity and much more similar dielectric properties compared to mineral oils than esters. In addition, NYTRO® BIO 300X provides the lowest viscosity profile of any bio-based insulating liquid in the market today, allowing thermal optimisation of a transformer due to improved convective heat transfer. NYTRO® BIO 300X meets and exceeds IEC 60296 Ed 5 (2020).

Bio-based and Biodegradability – What is the difference?

NYTRO® BIO 300X is both fully bio-based (ASTM D6866) and readily biodegradable (OECD 301) but often these two concepts are confused. A bio-based product is one that is comprised of materials of biological origin apart from fossil materials and/or those incorporated into geological formations. The bio-based carbon content of a substance is a smart way of checking whether the actual material itself is predominantly bio-based where radiocarbon analysis of the Carbon-14 is used. NYTRO® BIO 300X comprises of >99% bio-based carbon, and as such is a fully renewable hydrocarbon. In addition, NYTRO® BIO 300X is readily biodegradable, but this has virtually nothing to do with the fact that it is bio-based. Biodegradability is a question of whether or not in nature the substance can be effectively broken down by living organisms. NYTRO® BIO 300X is a very pure, non-ecotoxic hydrocarbon, with relatively low average molecular weight compared to typical mineral insulating oils and these are the main reasons why it is readily biodegradable. In conclusion, if an insulating liquid on the market is claimed to be readily biodegradable this does not speak whatsoever to the origin of the material itself.

Questions to always ask about an alternative liquid:

- ✓ What is the bio-based carbon content?
- ✓ Is it readily biodegradable?
- ✓ Is it recyclable?
- ✓ What additives at what concentration are used in the product?



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What about Carbon Footprint?

Accounting for raw material sourcing, transports and production (cradle to gate) as well as the carbon sequestration by the feedstock during early life, NYTRO® BIO 300X has a negative carbon footprint. If compared to natural esters – which are vegetable seed oil based, they will typically have a higher carbon footprint. NYTRO® BIO 300X is also competing far less with food-crops. This is because most natural esters are made from the same oils that are used in the food industry. In the case of NYTRO® BIO 300X the majority of feedstocks are by-products rather than the main crop itself. In many cases the water usage footprint of vegetable crops is very high, and this should be taken into consideration when evaluating a bio-based product. NYTRO® BIO 300X is also fully recyclable and the reclamation and re-refining technologies that are used today on mineral oils are completely sufficient to be applied on NYTRO® BIO 300X. In comparison, the recycling technologies available for ester liquids is limited. Re-refining via hydrotreatment is not an option for esters, but it is for hydrocarbons. Reclamation via adsorbents (such as clay) is more complicated for esters due to their polar nature and the different additives which may need to be replaced.



NYTRO® BIO 300X has outstanding oxidation stability meeting and exceeding the highest requirements on the accelerated ageing tests according to IEC 61125, i.e. no significant acid production after 500 hours at 120°C in the test.

Why is Oxidation Stability important?

It is well known in the energy industry that power transformers are expected to have a long useful life, usually 40 years. In fact, even longer design lives are desired to improve capital expenditure and for better sustainability. Utilities and asset operators do not want to have to do any major maintenance on a transformer over this period. Insulating oil maintenance usually involved activities such as inhibitor top up, oil reclamation or oil replacement. To minimise required insulating liquid maintenance using a product with excellent oxidation stability is the best solution. NYTRO® BIO 300X has outstanding oxidation stability meeting and exceeding the highest requirements on the accelerated ageing tests according to IEC 61125, i.e. no significant acid production after 500 hours at 120°C in the test. Natural esters have very poor oxidation stability (typically only 48 hours in the same test and they produce acids) as a consequence, natural esters are only really a viable solution in hermetically sealed transformers in a distribution context. As transformers get larger than around 1 MVA and above 33 kV, it becomes more challenging to achieve a hermetically sealed design (due to thermal expansion and contraction). Mid-size and large power transformers will typically have a conservator and even if a rubber bag is employed, the use of natural ester should be carefully considered because if there is oxygen ingress, the natural ester will experience much faster oxidation than utilities are accustomed to with mineral oils. NYTRO® BIO 300X has no limitation for use in fully free breathing transformers thanks to its excellent oxidation stability.



Insulating Liquid	Viscosity at 40°C
NYTRO BIO 300X	3.7 cSt
NAPHTHENIC MINERAL OILS	7.6 – 11 cSt
SYNTHETIC ESTERS	29 - 34 cSt
NATURAL ESTERS	32 – 40 cSt

Why is Low Viscosity important?

A power transformer is first and foremost an electrical machine, but coming in at a close second, it is a thermal machine. Heat is generated due to the losses, and ambient temperature as well as load fluctuations lead to temperature gradients within the unit itself. Heat must be removed as efficiently as possible to ensure a transformer will operate reliably over the many decades of its operational life. The insulating liquid acts as a heat transfer fluid and lower viscosity means better heat transfer, and lower temperatures. Natural and synthetic esters are much thicker and more viscous liquids than mineral oils and compared to NYTRO® BIO 300X they are about 10 times more viscous. Practically, if one took a transformer of a certain design, and only changed the liquid and nothing else, the one filled with NYTRO® BIO 300X would have a significantly lower winding and hot spot temperature, typically 8 to 15 degrees lower than the one filled with ester, depending on the transformer's design. Lower viscosity liquids lead to lower temperatures for a given design, especially where (liquid) natural convection is employed [6]. With NYTRO® BIO 300X, transformer designs can be optimised to potentially save on copper and overall size, because of the expected reduced temperature on standard design (mineral oil), and thus providing a significant margin to the guaranteed temperature rise requirements.

How important is Fire Point?

Natural and Synthetic esters have higher fire points than typical mineral insulating oils but the positive impact this has on transformer reliability is often exaggerated. First of all, the fire point of a liquid speaks only of its combustibility, not of its electrical behaviour within the transformer. In fact, both natural and synthetic esters are more likely to initiate electrical discharges, in certain situations, in a transformer than mineral oils and their ability to quench the arc itself is less effective than it is in mineral oils [1-3, 7, 8]. As a consequence, ester filled transformers are usually designed with higher electrical safety margins and are mostly limited to vacuum type tap changers. Both mineral oil and ester filled transformers can explode [9]. The risk of an explosion in a transformer is not related to its liquid's fire point but rather to the pressure wave a sudden electrical arc will cause and whether the tank can handle the pressure wave. What is debated is the consequential fire. It is rather well known in the industry that, historically, the root cause of the majority of transformer fires was bushing and tap changer failure [10], with both technologies becoming much more reliable in recent years. The issue needing more debate and investigation in the industry is: if the bushing and tap changer are of a modern, safer design, does the overall consequential risk of transformer fire really get significantly improved by moving to an ester liquid? Combined with the fact that esters have worse, not better, dielectric properties, and dielectric failure being often the main issue in transformers [10], one needs to critically evaluate the true benefit of a higher fire point.



Does the transformer design change?

As NYTRO® BIO 300X shares much in common with the best mineral insulating oils, for the most part transformer designs will remain unchanged. The lower viscosity of the liquid (better heat transfer) will in fact incentivise thermal design optimisation. Through close collaboration with leading transformer manufacturers, tap changer manufacturers and research institutions, a large body of scientific know-how already exists on the product. Typically, tap changer ratings used for mineral oils can be applied (whereas more safety margin is normally needed for esters [1]) and the overall dielectric design of the transformer is expected to remain mainly unchanged (whereas for esters electrical design rule changes are usually required [2]). As already mentioned, due to excellent oxidation stability, there is no restriction for the type of preservation system and free breathing transformers can be used.



Can I use existing diagnostics?

NYTRO® BIO 300X is a hydrocarbon-based liquid much more like mineral oils than ester liquids. Ester liquids have a completely different chemical composition and as such there have been many questions into the type of gases they will produce under fault conditions and whether current day DGA rules are applicable. Moreover, ester liquid usually contains different antioxidant additives (and more of them) than used in inhibited mineral oils, so there are also questions around liquid ageing, and inhibitor management. For NYTRO® BIO 300X the same inhibitor is used that is used in other NYTRO® naphthenic based inhibited insulating liquids and the same inhibitor monitoring and top-up regimes apply. Regarding DGA, no significant differences in DGA interpretation to existing mineral insulating oils are expected, due to similarity in chemical composition with other mineral and hydrocarbon based insulating liquids; nonetheless, ongoing and continuous research will supplement the body of knowledge over the next years.

How do things change on site?

A practical challenge ester liquid brings to the table is the need for two sets of oil treatment equipment as well as different on-site filling practices. Firstly, cross contamination between an ester and a mineral insulating oil can ruin the properties of the mineral oil – for example, properties such as the Inter Facial Tension (IFT) and Dielectric Dissipation Factor (DDF) can change drastically. As a consequence, product segregation between mineral oils and ester liquids is needed. Ester liquids have higher viscosity and higher water retention than mineral oils and as such will require different treatment rates in oil purification plants. The filling process in the transformer will also take longer and be more complex as the insulation impregnation time will take longer for ester liquids [11-13]. For NYTRO® BIO 300X flushing between products will be sufficient to enable the use of the same treatment plants and pipes, and the filling process can remain the same as for mineral oil. In fact, the insulation impregnation rate will be faster than for mineral oils because of the product's low viscosity.





Conclusion and summary

NYTRO® BIO 300X is one of the most exciting innovations in the insulating liquid space in recent years. With keen interest from the market, NYTRO® BIO 300X will be at the forefront of the drive towards improved sustainability of transformers. This is achieved both by the lower carbon footprint of the material itself combined with the potential for a lower energy footprint of the transformer. If the transformer designer makes use of the improved heat transfer the liquid offers and the transformer has a lower winding temperature than the specification limit, then load losses will be reduced for the same load. NYTRO® BIO 300X shares many similarities with the best mineral insulating oils but has the added benefits of being fully bio-based, readily biodegradable and of ultra-low viscosity.



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