TECHNICAL BULLETIN

IsoTec
Reliable. Safe. Sustainable.

ISOTEC STORAGE,HANDLING AND TREATMENT

DISCLAIMER

Products produced by Vielhauer GmbH conform to all associated industry standards in relation to product safety. This manual is to be used as a guide and is not a direct substitute for training and/or experience with respect to using equipment in a safe manner. Only capable personnel with the appropriate qualifications should operate, maintain, and install equipment mentioned in this guide.

SCOPE

The IsoTec dielectric liquid range includes:

- Natural esters: IsoTec NE 350 is rapeseed/canola crop-derived
- Synthetic ester: IsoTec SE 300

International standards apply to these esters:

Liquid	Condition	IEC	IEEE	ASTM
Synthetic Ester	New Used	61099	C57.166**	WK46195**
	New Used	61203*		
Natural Ester		62770*	C57.147	6871
		62975	C57.166**	

* Standard underreview **Newstandard under development

This document provides treatment, handling, and storage guidance, in alignment with the standards summarised above and it applies to both the natural and synthetic IsoTec products.

RECEIPT AND TESTING

Receipt

When receiving “unused” IsoTec SE 300, it should pass all quality criteria in the IEC 61099 standard . When receiving “unused” IsoTec NE 350, it should pass all quality criteria in the IEC 62770 standard. Once it has been used to flush pipework, to energise a transformer or for any other application, it may not be of the same quality as when first tested. As such, IEC61203 (synthetic ester) or IEC62975 (natural ester) should be used. For example, it is not unusual for dielectric dissipation factor (DDF)/tan delta of IsoTec SE 300 to increase beyond the IEC 61099 specification of 0.03 after use.

“Unused” IsoTec NE 350 when tested in accordance with IEEE C57.147

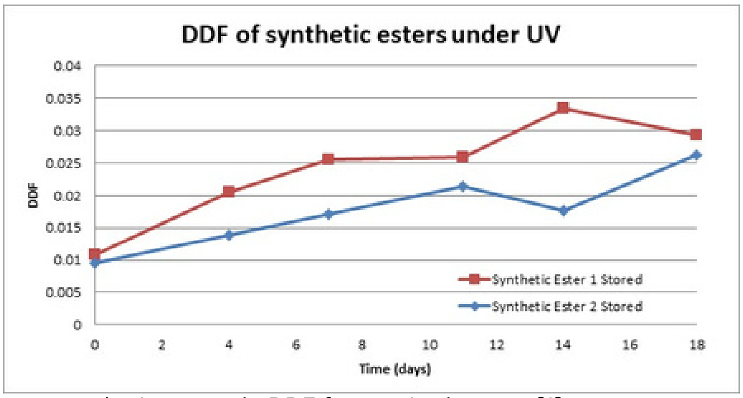
standard meet the requirements of Table 2 “Acceptable values for receipt of shipments of unused natural ester liquids” or IEC 62770. Once the liquid is used to flush pipework, stored in bulk storage at transformer manufacturer or filled in a transformer prior to energization, the properties of the natural ester liquid should meet the requirements of Table 3 in IEEE C57.147 or Table 3 in IEC 62975.

Sampling
The same care should be taken when sampling IsoTec for quality testing as with any other dielectric liquid and IEC 60475 guidance should be followed. Sample jars must be clean and dry. The jars should then be rinsed once with the IsoTec and emptied to waste, before drawing the final sample and closed. The jars should be opened only for as long as it takes to obtain a sample. Jars left open can experience water ingress and gas absorption, such that subsequent sample analysis is not representative.

STORAGE

Drum and IBC (tote) storage
If properly stored indoors,away from direct exposure to sunlight, and in the recommended temperature range (IsoTec SE 300 -40°C to 40°C; IsoTec NE 350 10°C to 40°C), unopened containers of IsoTec typically haveashelf life of 10 years. The shelf-life figure of 10 years is given as a guideline only and is notastrict limitation on the length of time that IsoTec can be stored. If stored beyond this time userscanestablish the suitability of the liquid for service by checking properties such as water contentandbreakdown voltage. It is fully expected that in a well maintained transformer, the IsoTec liquidwill provide many years of good dielectric performance, and that the length of the IsoTec workinglife is not limited to the stated shelf life.

Prolonged exposure to ultraviolet (UV) light can increase the DDF in synthetic ester (Figure 1a), or bleach natural ester over time (Figure 1b). For this reason, IsoTec is supplied in opaque containers, and the ideal storage location will be indoors to avoid extremes of temperature and exposure to the weather.



a) Increase in DDF for synthetic ester [1]

b) Bleaching effect in natural ester

Figure1:Effectsonesterliquids due to prolonged exposure to UV

Once opened, precautions should be taken to avoid contact with moist air for prolonged periods because the liquid is hygroscopic and will absorb atmospheric water. If a partially emptied container is used for storage, the head space should ideally be backfilled with dry air (IsoTec SE 300 only) or dry nitrogen prior to resealing. If this is not possible, then ensuring the lid is properly sealed will help keep the liquid dry.

DDF, as a quality metric – although carried over from the mineral oil application – should not be applied as a primary quality measure in esters. High DDF will indicate contamination in a mineral oil and ester liquid. However, because ester is a more polar molecule than mineral oil, *small increases* in DDF in ester are not accompanied by changes to other quality parameters such as breakdown voltage [1]. For this reason, it is recommended that acid value can be a more reliable measure of ester condition. Contact IsoTec for further advice on DDF analysis if required.

IsoTec is not able to accept empty IsoTec IBC's back for reuse. However, sustainability is important to us, and we are aware of companies offering this service including Mauser Packaging, Centurion Container, Greif, Container Management Services, and Schütz. Note that IsoTec does not endorse any of these providers, and you will need to satisfy yourself as to the suitability of their services for your requirements.

Storage tanks

IsoTec storage tanks are generally stainless steel, grades 304 or 316. Those used previously for mineral oil transformer liquid may be used but must be cleaned appropriately first (see below).

For IsoTec NE 350, it is recommended that a tank headspace of dry nitrogen is used to keep out water and to reduce the oxidation risk associated with all natural esters. Due to the superior oxidation stability of IsoTec SE 300, if a nitrogen blanket is not possible, then dry air should be used in the headspace and a suitable breather unit fitted to the vent system. If a silica gel breather is used to dry the headspace air, this must be properly maintained to ensure that the liquid quality is preserved.

IsoTec SE 300 should be stored between -40°C and 40°C and IsoTec NE 350 between 10°C and 40°C.

As the viscosity is higher than that of mineral oil, it may need to be heated for transfer depending on the pump used (see section on pumps below). If heating is required, this can be done through heat tracing of the storage tank and pipework (see heating section below). Insulation can help maintain temperature and reduce losses to the atmosphere.

Miscibility

Miscibility gives an indication of the compatibility between different liquids. IsoTec is fully miscible with transformer mineral oil, high molecular weight hydrocarbons and other transformer ester liquids. It is **not** miscible with silicone liquid. If unsure about the miscibility of a specific insulating liquid with IsoTec, please contact IsoTec for recommendations. In order to retain the fire safety classification (fire point: IEC 61039 K class >300°C; less flammable liquid ≥300°C), residual mineral oil is generally limited to <3.5% for IsoTec SE 300 and <7% for IsoTec NE 350.

HANDLING TO AND FROM TANKS AND TANKERS

Cleaning

For a storagetankortanker truck previously filled with mineral oil, it is recommended to thoroughly clean it beforefillingwith IsoTec. If steam cleaning is performed, ensure that the storage tank or tanker truckiscompletely dry before filling it with IsoTec. If IsoTec is used to flush remaining mineral oilfromastorage tank or tanker then the user must ensure that a sufficient volume of IsoTec isusedtoremove all residual mineral oil. A rinse with IsoTec of the transfer pipes, isolation valves and/orpumponthe storage tank or tanker system is also recommended.

Inspection

Storage tanksandtankers should be inspected to ensure that they are clean and free of contaminants.Contaminants may include, but are not limited to dust, paint, metallic particles or rust, fabricationdebris,oilsludge or water. Inspection of IsoTec should be done with those methods used for mineraloil.Before filling the tanker, the certificate of compliance by the supplier should be checked tomakesurethat IsoTec meets all the specification requirements.

Unloading

IsoTec should be unloaded using a similar method to that used for mineral oil, but attention should be paid tothe filters, pumps, valves, seals, and hoses. Dedicated equipment for IsoTec will yield optimal performance. See below for guidance on earthing and static, and the oxidation risk for natural esters.

Filtration

IsoTec should be filtered before filling the tanker truck and after unloading it in the storage tank or in a transformer. The filters recommended for IsoTec are 1 micron absolute of a type suitable for use with transformer oil. A cartridge type filter with a synthetic filter medium may be used. Filters should not use plastic seals to avoid electrification issues. It is suggested that beta (β) ratios above 75 will generally indicate a high filter efficiency when comparing suppliers. If unsure about a particular filter, please contact IsoTec for recommendation. A good general practice is to filter IsoTec every time it is transferred. Due to its viscosity, IsoTec filtration may be slower than mineral oil, while heating reduces its viscosity – see Table 2 and Figure 3.

Heating for storage and pumping

Indirect heating systems (such as steam jackets) are suitable for use with IsoTec. Avoid a concentrated heat flux as this can increase DDF. It is recommended that the heat density of the chosen system should be no more than 1.0 W/cm2. Multi-stage heaters are recommended when increasing temperature over a large range with each stage offering the opportunity to control temperature, ensuring that the liquid does not become overheated.

If a pump is feeding the heater, then a flow switch is required. Heaters are required to be powered down to avoid possible localised overheating when there is lack of flow. A time delay should be used on the recirculating pump so that it turns off only after the heaters have been powdered down for sufficient time. Immersion heaters should not be used.

The viscosity of IsoTec is higher than mineral oil at ambient temperatures and this must be considered when specifying pumping systems. A higher capacity pump will be needed to maintain the same flow rate as mineral oil at a given temperature. Figure 2 is provided to assist with pump specifications to transfer the liquid at the lowest foreseen temperature and related viscosity.

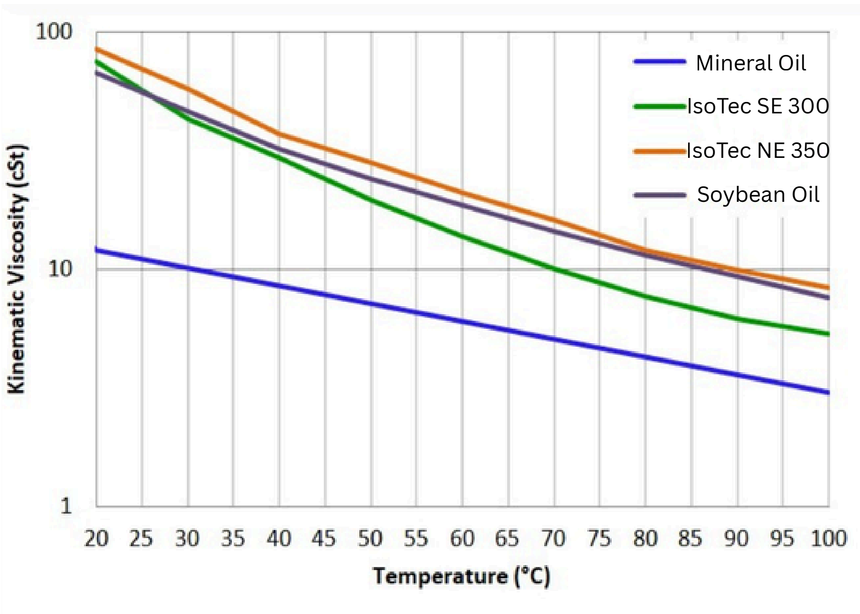


Figure 2: Viscosity vs temperature - considerations for pumping IsoTec

Itis highly recommended to have dedicated hoses and pumps for IsoTec, toprevent cross-contamination. Where the same hoses, pumps or pipework are used for transformermineral oil and IsoTec, it is recommended that these items/installations are thoroughly flushed withIsoTec prior to use (see below on natural ester oxidation stability considerations) and to discard theliquid used for flushing.

Earthing and static

As with any dielectric liquid, there is a possibility of electrostatic charge accumulation (streaming electrification) when IsoTec is flowing through hoses and pipes to fill tanks, tankers, and transformers. The user should ensure that all pumps, lines, and vessels are adequately bonded and earthed during pumping operations. A maximum pumping velocity of 0.5 m/s is recommended:

Pipe diameter	Flowrate (max recommended)	
1.0" (DN25)	1000 l/h	264 US gal/hr
1.5" (DN40)	2500 l/h	661 US gal/hr
2.0" (DN50)	4000 l/h	1057 US gal/hr
3.0" (DN80)	7000 l/h	1849 US gal/hr

Materials Compatibility
Allhoses, seals, pumps, and valves should be compatible with IsoTec. A material compatibility list is available on the IsoTec website.

www.isotec.bio

If a different material is required, contact IsoTec for advice.

TREATMENT

Drying
IsoTec has a much higher water saturation point than mineral oil and this property impacts on the water thresholds set for factory treatment to obtain electrical properties similar to those for mineral oil.

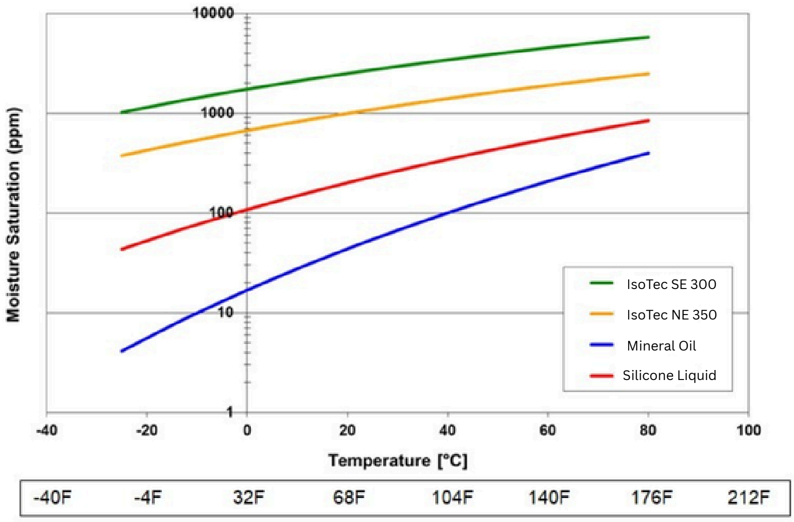


Figure 3: Water saturation vs temperature [2]

For example, at 80°C and 50ppm water content, the relative saturation of IsoTec SE 300 is less than 1% therefore further degassing is not necessary (equivalent to 80°C mineral oil with a water content of <3ppm). If the water content rises beyond acceptable levels then it can be removed as follows:

For free water removal from IsoTec:

- Use cartridge water removal filters (i.e. those containing desiccants)
- Raise the temperature of IsoTec to 80°C and agitate while in a dry nitrogen atmosphere

For dissolved water removal from IsoTec:

- Use a vacuum dehydration system (see more details in sections below)
- Use molecular sieves – Grades 3A and 4A are recommended

Vacuum dehydration – Degassing

Vacuum dehydration can be done prior to using IsoTec if desired, to further reduce the water and gas content of the liquid. IsoTec does not need to be dried to 5ppm to meet the same water saturation percentage as mineral oil:

Liquid	Ester Groups in molecular structure	Saturation Limit @ 20˚C (68°F)	Relative water content @ 20˚C (68°F) & 5ppm absolute water	Saturation Limit @ 60˚C (140°F)	Relative water content @ 60˚C (140°F) & 5ppm absolute water
IsoTec SE300	4	2700ppm	0.19%	4500ppm	0.11%
IsoTec NE 350	3	1100ppm	0.45%	1900ppm	0.26%
MineralOil	0	55ppm	9.09%	207ppm	2.42%

Drying IsoTec to an absolute water content between 40 and 60ppm is recommended. Lower water levels are not beneficial and can negatively impact the breakdown voltage of the liquid:

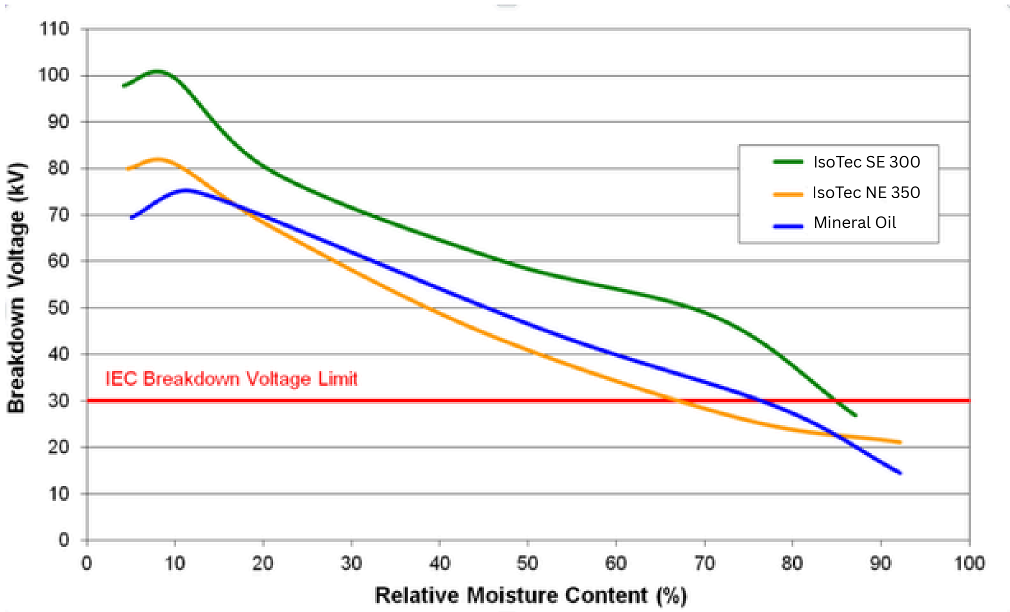


Figure 4: Effect of relative water on breakdown voltage [3]

The water content of a dielectric liquid will influence water levels in the insulatingpaper of the transformer. Figure 5 demonstrates that a water content of 40-60ppm in IsoTec willsatisfy even stringent internal requirements for paper water content below 1%.

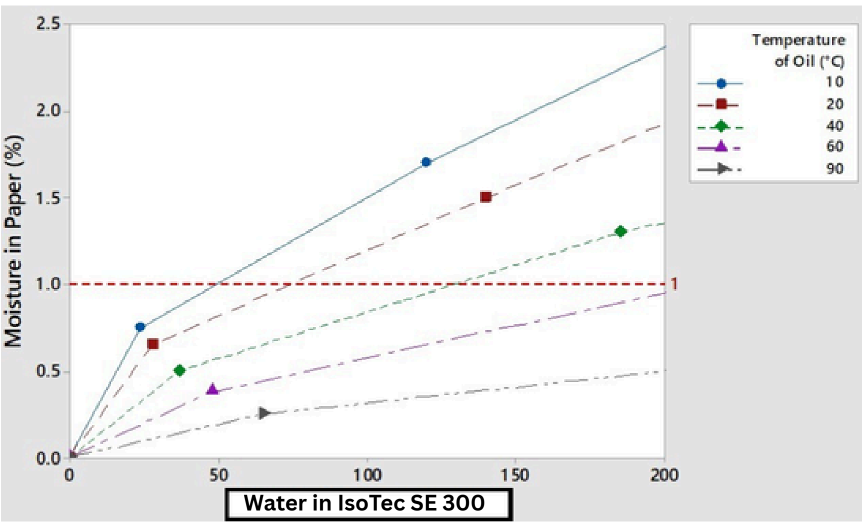


Figure 5: TypicaldatarangesforwaterinalsoTecinsulationsystemwithcellulose

Drying under vacuum in the degassing stage requires balancing several operating parameters and general guidance is provided below:

Parameter	***Value / Optimum Choice***	***Function***
Watt density of heater/s	< 1.0 W/cm2	This is vital to ensure that any increase in DDF due to molecular bonds breaking is slowed
Vacuum pressure	1-2mbar	To facilitate water removal when at temperature
Liquid temperature in vacuum chamber	80-100˚C (176-212°F)	To facilitate water removal when under vacuum
Heating system	Multi-stage heating	To maintain a low watt density while heating the liquid
Heater control system	PID control	To maintain a suitable temperature through continuous feedback
High temperature thermal shut-off switch	105˚C (221°F)	Failsafe to prevent damage to liquid / transformer
Low flow-switch	The flow is dependent on the system and should be estimated by the user.	Heaters will not operate should there too little flow, preventing damage to liquid.
Heater off and pump off time delay	The delay is dependent on the system and should be estimated by the user.	The heater will switch off and then after a time the pump will switch off too. This will prevent damage to IsoTec by eliminating a higher rate of heat flux than normal (where the liquid is stagnant).

A booster pump may be required to increase the throughput when removing water as it is separated from IsoTec. This should be sized accordingly. Note that the main vacuum pump should be able to attain the required vacuum level (2mbar) alone i.e. If IsoTec has a water content of 150 ppm and a reduction to 50ppm is targeted, then using a flowrate of 3,000 L/hr (793 US gal/hr), a booster pump with 70 L/s (18.5 US gal/s) capacity will be required as a minimum.

At 80°C (176°F) and 50ppm water content, the relative saturation of IsoTec is less than 1%, therefore further degassing is not necessary. To acquire a water level of 50ppm, a vacuum below 2mbar is not required when operating at 80˚C (176°F). When degassing at 2mbar and 80-100˚C (176-212°F) there is also no chance that IsoTec will be vaporized:

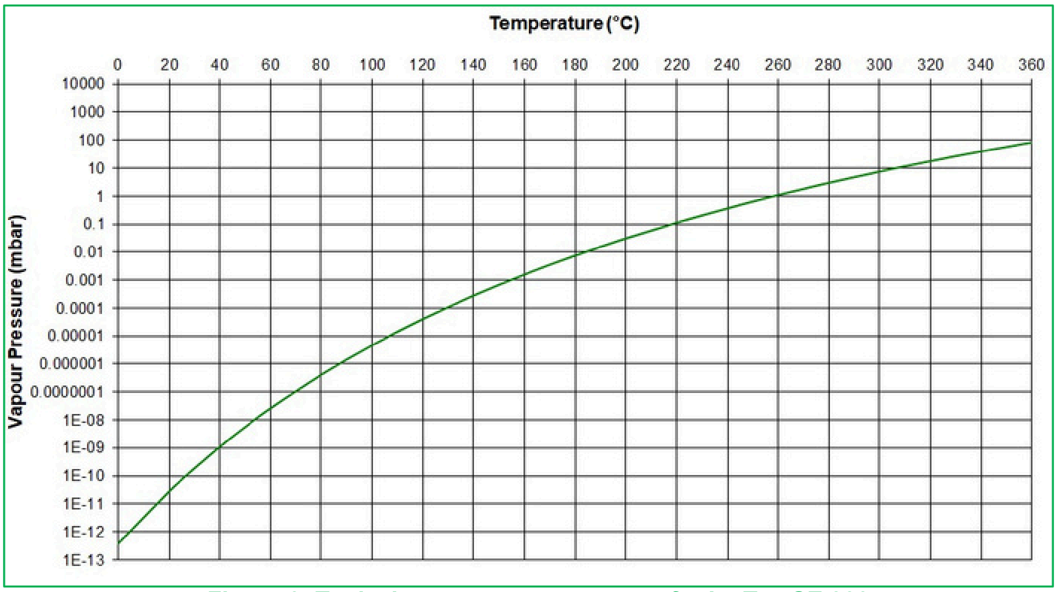


Figure 6: Typical vapour pressure curve for IsoTec SE 300

Solid insulation impregnation

In practice, impregnation is driven by viscosity and the quantity of solid insulation inside a transformer. An ester temperature of 80-100˚C (176-212°F), but at least 60˚C (140°F), should be maintained during impregnation. Ideally, impregnation times should be increased by 30% for power transformers if using ester at 90˚C/194°F (compared to mineral oil at 60˚C/140°F). Note that the higher viscosity of natural ester may require additional time compared to IsoTec SE 300:

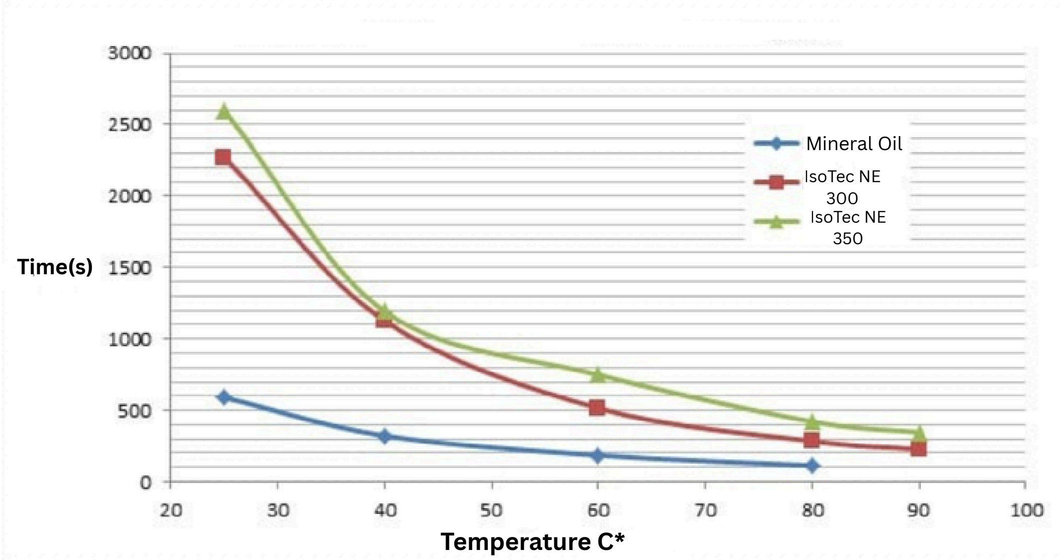


Figure 7: Impregnation time for 100mm of pressboard (MO vs IsoTec) – note the different starting temperatures

Impregnation holes are an effective way to reduce impregnation time [4] and should be used if deemed appropriate. The overall time could be reduced by as much as 75%. Figures 8 and 9 show that impregnation holes reduce the overall path the liquid must travel before reaching full impregnation, thereby saving time.

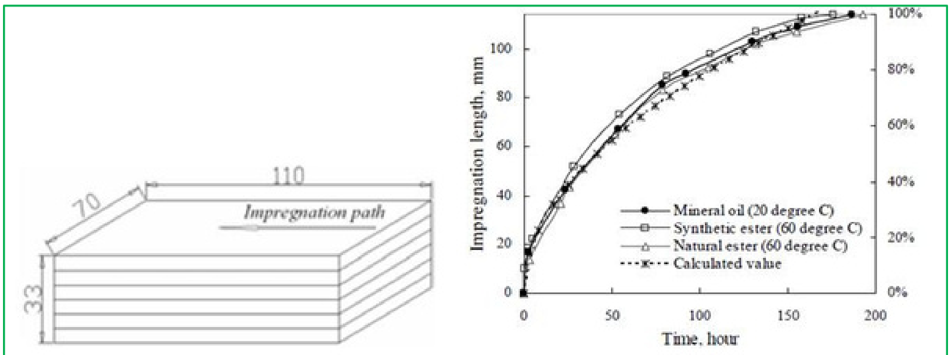


Figure 8: Regular impregnation path [4]

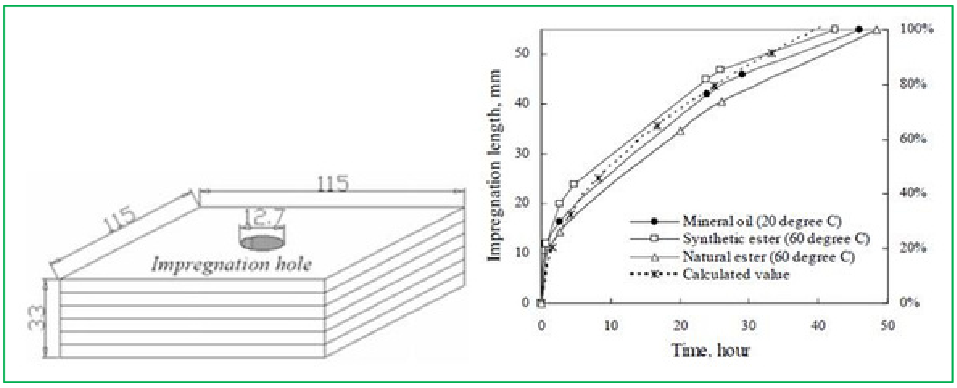


Figure 9: Impregnation path assisted with holes in solid insulation [4]

Temperature should be maintained throughout the process by recirculating the IsoTec through a heater. The heater specification / operation should match the relevant points made previously in this document. If water levels are already between 40 and 60 ppm, it is recommended that any vacuum is turned off. By recirculating the liquid, users should again be aware that liquid parameters should be assessed against "after filling & prior to energisation" values in IEC 61203 (IsoTec SE 300) or IEC 62975/IEEE C57.147 (IsoTec NE 350): after handling, it is not unusual for the DDF to rise slightly. The decision to recirculate the liquid or accept slower impregnation times lies with the user.

Transformer filling

Figures 10 & 11 show how different transformers can be filled while maintaining temperature for an efficient impregnation.

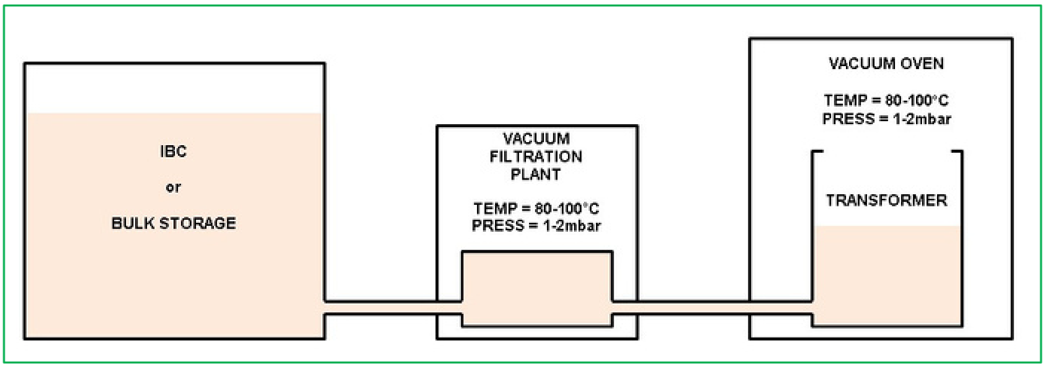


Figure 10: Typical distribution transformer filling with IsoTec: base filling

The first fill of a power transformer should avoid splashing, thus negating aeration andpossible static discharge. This can be done by bottom filling, either from the base of the tank/transformer or through a dip pipe which goes toward the bottom of the tank as shown below.

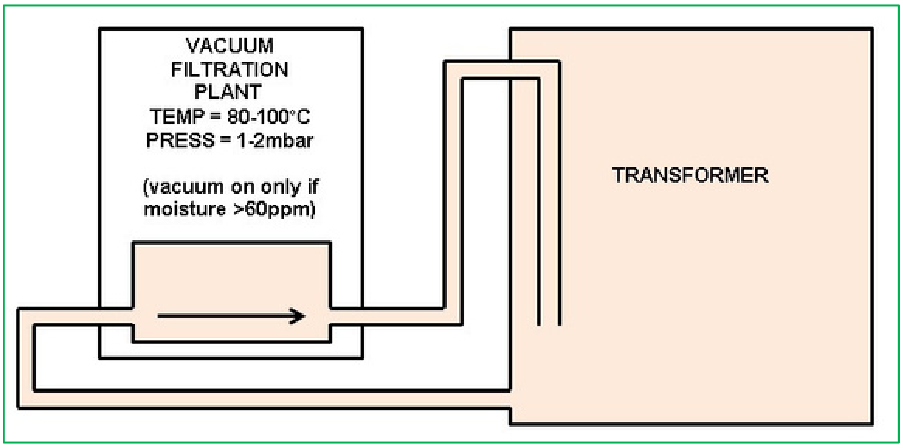


Figure 11: Typical distribution transformer filling with IsoTec: base filling via pipe insert

- Filling from the base of a tank also prevents air entrapment in the transformer cellulose. Using a
- vacuum to fill prevents foaming (which can be redressed with further degassing if required).
- Dry air (IsoTec SE 300 only) or dry nitrogen should backfill the storage container as the IsoTec exits the latter and fills the transformer.

Natural Ester Oxidation Stability Considerations

The oxidation stability of natural esters, including IsoTec NE 350, is significantly inferior to that of synthetic esters such as IsoTec SE 300. For this reason, IsoTec recommend natural esters are only suitable for non-free breathing transformer applications, and IsoTec NE 350 is expected to perform for the life of a sealed transformer. However, extended periods of continuous contact with oxygen in the air may allow natural esters to oxidise, therefore good manufacturing practices should be followed to minimise the amount of continuous contact with air. When natural esters oxidise the impact may be experienced either as a thin film on an exposed surface that initially becomes sticky after a number of days before polymerising and hardening to a varnish over following weeks, or in a bulk volume where the viscosity increases slowly over time without becoming sticky.

In practical terms this has the following implications:

- Active parts impregnated with IsoTec eN liquids must not be dried in a hot air drying oven Service
- and processing equipment used for IsoTec eN should be rinsed with IsoTec SE 300 to remove
- residual natural ester Thin film oxidation on surfaces in a transformer drained for maintenance can be reduced by
  rinsing the tank and core/coil in IsoTec SE 300, placing transformer/assemblies within a large plastic bag filled with nitrogen, or placing the assemblies in a volume of liquid.

Contact Vielhauer for further advice on natural ester oxidation stability risk management if required.

REFERENCES

1. *P. Livesey, M.Lashbrook, R. Martin (2019) Investigation of the factors affecting dielectric dissipation factor of synthetic and natural ester, IEEE International Conference on Dielectric Liquids 2019.*
2. *Tenbohlen, S. and Koch, M. (2010). Aging Performance and Water Solubility of Vegetable Oils for Power Transformers. IEEE Transactions on Power Delivery, 25(2), pp.825–830.*
3. *Dai, J. and Wang, Z. (2008). A Comparison of the Impregnation of Cellulose Insulation by Ester and Mineral oil. IEEE Transactions on Dielectrics and Electrical Insulation, 15(2), pp.374–381.*

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