

# RETROFILLING TRANSFORMERS WITH ESTER FLUIDS

The top 15 questions answered



# WHY RETROFILL A TRANSFORMER?

We get a lot of questions on ester fluids – especially when it comes to retrofilling transformers. That's why we've put this guide together on the top 15 questions (and answers) – to help organisations better understand the challenges and possibilities of retrofilling with ester and to assist them to make investment decisions with greater certainty.

## Retrofill reasons

The motivations for power and distribution transformer retrofilling are numerous. They range from addressing an urgent need on a single asset, to rolling out a network-wide program with clear financial returns.

Each transformer has unique operational factors that influence the situation such as load, asset design, age, location, and environment.

## Reducing risk with minimal cost

Risk is the most common reason for retrofilling mineral oil filled transformers with an FM Global approved ester fluid. Synthetic and natural esters like those from MIDEL can deliver significantly reduced risk with minimal CAPEX and OPEX.

Often at the top of the risk list is a reduced risk of collateral damage. This in turn can lead to other cost savings such as enabling fire mitigation equipment to be removed from service, eliminating maintenance, avoiding CAPEX on costly site works such as fire walls or transformer relocation.

When retrofilling mineral oil filled transformers with a **natural ester** or **synthetic ester** fluid there are additional financial incentives that support positive ROI.

This is due to the unique capabilities of ester fluids and their performance in transformers, resulting in cost savings without sacrificing reliability.

Many transformer owners can financially justify ester fluid retrofills based on **just one of these factors**. When multiple factors are evaluated together, they **create a very compelling business case for retrofilling** with ester fluids.



### FIRE SAFETY

reduced risk through much higher fire point and flash point



### SAFETY COMPLIANCE

meet fire codes, insurance audits; clearances, fire wall, deluge system



### ENVIRONMENTAL IMPACT

minimise environmental impact and facilitate policy compliance



### SPILL REMEDIATION

simplified and less costly bio remediation and containment



### OIL QUALITY

decrease the levels of undesired contaminants and dissolved gases



### LIFE EXTENSION

significantly beyond what is possible with mineral oil



### SLOW THE AGEING RATE

and delay capital investment for transformer replacement



### OVERLOAD CAPABILITY

gain increased safe overload



### REDUCE MOISTURE

Lower water content in the oil



### PCB CONCENTRATION

remove contaminated oil

# POSITIVE RETURN ON INVESTMENT

Retrofilling mineral oil filled transformers with ester fluids can deliver a positive return on investment. Some of the contributing factors include:

- **Additional 20°C tolerance** provided without accelerating normal insulation system aging rate (achieved through additional loading)
- **Fire mitigation equipment** can be removed from service, eliminating some maintenance expenses
- Costs incurred to **remediate future spills** may be reduced
- Reduced risk of **dielectric failure caused by bubble formation** during overload
- Reduced risk of collateral damage to other equipment by not incurring **dielectric pool fire**
- **Avoid capital expenditure** on costly site works, such as fire and blast walls

Many mineral oil filled transformers are being pushed beyond nameplate rating even though the exact condition of their cellulose insulation is unknown. Such practices accelerate the aging of the paper insulation, potentially reaching end of life.

Fortunately, replacing mineral oil (retrofilling) with natural ester fluid is a cost-effective way to slow the thermal aging rate of insulation, enabling increasing load-ability of transformers.

## Synthetic or Natural?

Synthetic and natural esters have been successfully used in retrofilled oil-filled transformers for more than forty years. Comparing these fluids reveals the full extent to which MIDEL esters offer a much higher performance level than mineral oil.

Both provide the crucial combination of K-Class fire safety and environmental protection – properties that are absent in mineral oil.

# A BETTER UNDERSTANDING OF MIDEL FLUID CHOICES FOR TRANSFORMERS

## Which MIDEL?

The MIDEL family of transformer fluids comprises MIDEL eN 1215, MIDEL eN 1204 and MIDEL 7131. The “eN” prefix denotes natural esters, which are formulated using renewable base oils from different seed crops, whilst MIDEL 7131 is a synthetic ester fluid. All MIDEL fluids are fully/readily biodegradable. MIDEL eN 1204 is the natural ester of choice for the Australian market.

### Natural Ester Fluid

**MIDEL eN 1204** is formulated from rapeseed/canola oil and is a cost-effective general-purpose fluid. Like all natural esters, it is ideally suited to non-free-breathing distribution and power transformers. This rapeseed/canola ester is suitable for use in all climates and has superior oxidation characteristics compared to soya ester fluids.

MIDEL natural esters meet the IEC 62770 standard.

### Synthetic Ester Fluid

**MIDEL 7131** is specifically formulated to be a fire safe, high-performance fluid providing all the benefits of ester technology in an extremely robust formulation. It is the fluid of choice when the performance demands on the transformer are higher, especially if located in a cold climate (it has a pour point of -56°C) or when there is a risk of contact with air.

In addition to being suitable and widely used for distribution and power transformers, MIDEL 7131 is also ideal for high temperature, breathing type equipment. It has a long track record in demanding applications such as wind turbines and rolling stock and is proven up to 433kV. MIDEL 7131 meets the IEC 61099 standard.

## Here are the top 15 questions on retrofilling transformers with MIDELE fluids.

1. Fluids miscibility
2. Free-breathing
3. Insulation regeneration
4. Fire safety classifications
5. Cold weather performance
6. Moisture absorption
7. Acid levels
8. DGA
9. Power factor
10. Materials compatibility
11. HV applications
12. Interfacial tension
13. Reusability
14. De-rating
15. Retrofill process

# #1 FLUID MISCIBILITY

## Which transformer oils are compatible with MIDEL ester fluids for retrofilling?

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**Miscible:** Mineral oil, high temperature hydrocarbon

**Not miscible:** Silicone oil

### Can silicone oil transformers be retrofilled with MIDEL fluids?

Retrofilling of a silicone filled transformer with an ester-based fluid needs very careful consideration, since the two types of fluid do not mix. Generally retrofilling of silicone filled transformers is not recommended, but if the user must exchange the fluid then please contact the Insulect technical team for further guidelines.

### Can residual mineral oil affect the fire point?

Residual mineral oil after retrofill can have an impact on the fire point of ester-based fluids. As a general guideline the following limits should be applied to maintain the fire point above 300°C.

**MIDEL 7131** < 3.5% mineral oil

**MIDEL eN 1204** < 7% mineral oil



Read more on miscibility and transformer oil compatibility in the Storage & Handling Guides: [MIDEL 7131](#) and [MIDEL eN 1204](#)

## #2 FREE BREATHING

### Can I use MIDEL fluids in breathing transformers?

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**There is a range of MIDEL fluids to suit all types of transformer preservation systems.**

For breathing transformers, we recommend the use of MIDEL 7131 which is oxygen stable and suitable for continuous contact with air.

For non-breathing transformers either MIDEL 7131 or MIDEL eN 1204 can be used. Typical transformer designs meeting the “non-breathing” classification include:

- **hermetically sealed** design with expandable radiators/corrugated tanks
- **oil conservator** design or retrofitted with a bladder/diaphragm/air seal, and
- **designs with nitrogen** or air head spaces incorporating pressure relief devices

### When is oxidation a concern?

**Natural esters have a much lower level of oxidation stability** than other liquids and if exposed to oxygen they can increase in viscosity over an extended time. This can reduce the cooling efficiency of the transformer, leading to an increase in operating temperature. For this reason, natural ester-based products are not recommended for breathing type transformers, where the liquid is continuously in contact with air. **For free breathing transformer applications, we recommend MIDEL 7131.**

# #3 INSULATION REGENERATION

## Will MIDELE fluids heal existing problems in a transformer?

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**No.** MIDELE fluids cannot “regenerate” insulation materials.

Degradation of the solid cellulose insulation in transformers (insulation ageing) is irreversible. Thermal ageing of cellulose materials cannot be avoided – however it can be slowed.

Retrofilling transformers with MIDELE fluids, can have a positive impact on the issue of paper ageing, delivering:

- **Longer life** for cellulose insulation at standard temperatures
- The option to run transformers at a **higher temperature** for standard lifetime
- The benefit of a **higher power output** or a **smaller footprint** by running transformers hotter

Using MIDELE ester transformer fluids can potentially extend the life of cellulose insulated transformers. Alternatively, transformers can be operated at a higher temperature with MIDELE fluids, while retaining the same lifetime they would have had with mineral oil at standard temperature.

# #4 FIRE SAFETY CLASSIFICATIONS

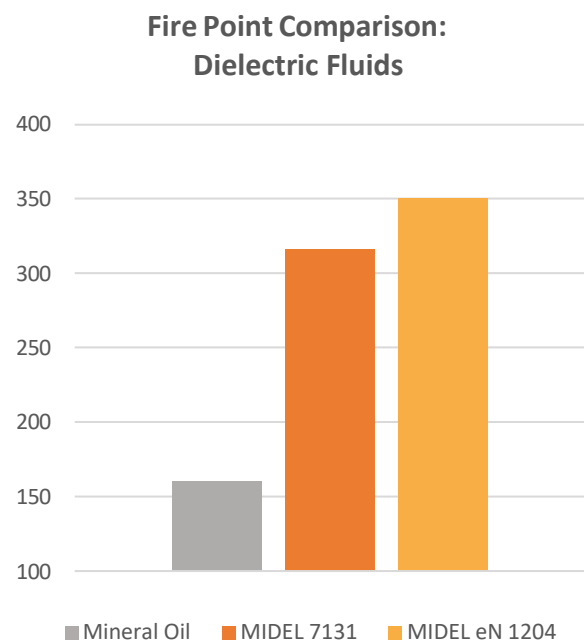
## Which dielectric fluids classifications are important to understanding fire safety?

IEC 61039 identifies “**fewer flammable fluids**” as those with a fire point >300°C. These are designated as K class fluids.

According to [IEC 61936](#) transformers filled with K-class fluids can have reduced fire protection measures.

In addition, certifiers such as FM Global provide a [list of approved Less Flammable Transformer Fluids](#) and guides for safe installation.

Using a high fire point fluid significantly reduces the chance of a pool fire.



### What does this mean for MIDE L?

There has never been an oil fire reported in the past 40 years in transformers using MIDE L ester fluids.



[Read More: The use of ester transformer fluids for increased fire safety and reduced costs](#)

# #5 COLD WEATHER

## How do MIDEL fluids perform in the cold?

There are a range of MIDEL fluids to suit various climatic conditions.

The performance of each fluid under cold climate conditions can be characterised by the pour point.

Transformer cold start procedures depend on the liquid type and temperature. Users can refer to [IEEE C57.93](#) or [IEEE C57.106](#) for guidance.

In line with other soy-based natural esters, the pour point of MIDEL eN 1215 is around -18°C, meaning that enhanced engineering controls may be needed for the coldest climate locations, e.g. heat tracing on conservator pipes.

Product	Pour Point
MIDEL eN 1215 (soybean)	-18°C
MIDEL eN 1204 (rapeseed)	-31°C
MIDEL 7131 (synthetic)	-56°C

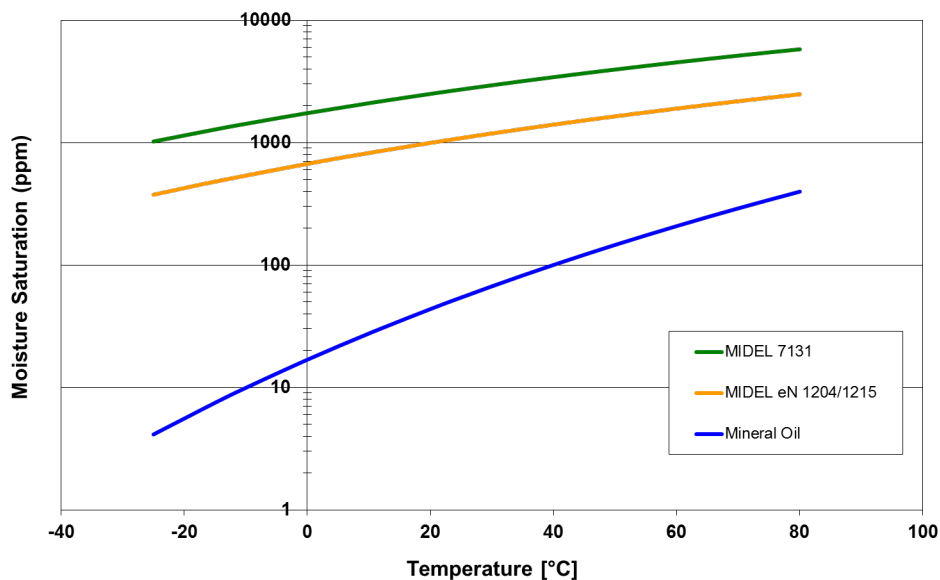
This requirement reduces with rapeseed-based MIDEL eN 1204 which has a lower pour point of -31°C. For extremely cold climates users may wish to opt for synthetic ester-based MIDEL 7131 which has the lowest pour point. MIDEL 7131 is in operation in the coldest regions of the world, including Siberia.

# #6 MOISTURE

## What happens to the performance of MIDEAL fluids when they absorb moisture?

Ester fluids can absorb large amounts of moisture with no reduction of breakdown voltage.

They have a higher saturation point – and are more tolerant of water – than mineral oil. A comparison of the saturation curves of different fluids is shown below.



### So, what happens in the transformer?

Water moves between the solid insulation and fluid trying to reach equilibrium in terms of relative saturation. Paper produces water as a by-product of thermal aging, which acts as a catalyst for continued degradation.

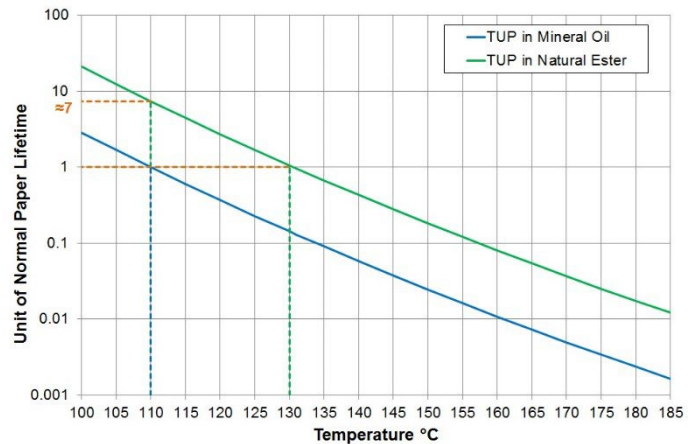
Because mineral oil has a very low saturation limit the water stays in the paper.

Since ester fluids have much higher saturation limits some water can migrate into the fluid, having a positive effect on paper aging rates.

## What does this mean for transformer life?

Laboratory experiments have demonstrated that cellulose materials immersed in ester-based liquids will age more slowly than those immersed in mineral oil.

Information on the enhanced aging of cellulose can be found in [IEEE C57.154](#) and [IEC 60076-14](#), including an aging curve which indicates that ester transformers can run hotter than mineral oil transformers for the same lifetime.



Alternatively, when run at standard temperature, a transformer can have a longer lifetime with MIDEL ester fluid.

## #7 ACID LEVELS

### If MIDEAL fluids have high acid levels, how do I recondition my fluid?

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**Mineral oil:** aging by-products are short chain acids, water soluble can catalyse paper degradation.

**MIDEAL fluids:** aging by-products are longer chain acids, not harmful to paper insulation.

Because of hydrolysis (the consumption of H<sub>2</sub>O and production of non-water-soluble long-chain acids) MIDEAL fluids can have higher in service acid numbers than mineral oil.

However, being longer chain the acids produced will not dissolve in water and will stay dissolved in the ester. The shorter chain acids from mineral oil are water soluble, will transfer to the paper and catalyse the aging of the solid insulation.

### Common transformer oil processing techniques

MIDEAL fluids can be processed using common equipment used for mineral oil. Materials and processes, including reconditioning (via degassing) and regeneration (using Fuller's earth) can be applied to MIDEAL fluids.

# #8 DISSOLVED GAS ANALYSIS

## How can I use DGA on MIDELE fluids?

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**Using much the same oil sampling and analysis methods you would use for mineral oil.** The gasses esters produce during electrical and thermal faults are the same as for mineral oil, but the quantities and relative amounts are slightly different.

A lot of the advice provided for DGA with mineral oil still holds true with esters. It is best to look at trends of results, rather than one off measurements and if possible fleets of transformers should be compared to each other.

IEEE C57.155-2014 is the ester dielectric fluid dissolved gas analysis standard.

MIDEL has a guide to dissolved gas analysis for ester fluids, which addresses questions such as:

- **How do mineral oil DGA methods differ to ester fluid methods?**
- **What should I expect when I see a DGA report for an ester fluid?**
- **How can I properly analyse DGA results for ester fluids?**

### What about stray gases?

All transformers produce stray gases during normal operation. Natural ester fluids produce different stray gases, primarily ethane, compared to mineral oil or synthetic ester fluid. These stray gases have been shown to be predictable and of no concern.

# #9 POWER FACTOR

## What is the Power Factor of MIDELE fluids?

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**Power factor is the ratio of resistance current to capacitance current in an insulation system.**

In new mineral oil transformers power factor is used to determine the level of insulation dryness. For operating transformers, changes in power factor can indicate increased levels of moisture or other contaminants in the insulation system. There are several variables that impact power factor measurements, even for new, essentially dry uncontaminated units, including:

- **the ratio of solid to fluid insulation**
- **the type of dielectric fluid**
- **winding design**
- **temperature at time of measurement**

### Understanding MIDELE Power Factor

The dielectric dissipation factor of ester-based liquids is higher than that of mineral oil, due to the polar chemical structure of the ester. This in turn leads to higher power factor values for clean, dry insulation than would normally be seen with mineral oil.

#### ***Distribution transformers***

Experience gained during the testing of transformers and published research has shown that the power factor of a new distribution transformer filled with MIDELE liquid will be around 50% higher than the same design with mineral oil.

#### ***Power transformers***

In power transformers the liquid to solid insulation ratio will be higher and therefore the ester liquid will have more influence on the power factor value. It should be expected that the power factor will be approximately doubled after retrofill in a power transformer.

# #10 MATERIALS COMPATIBILITY

## Are MIDELE fluids compatible with all transformer materials?

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**As a rule, components and materials used in mineral oil transformers are also compatible with MIDELE fluids.**

The M&I Materials technical department has compiled a study based on thorough testing and research, which they continuously conduct. The compatible and incompatible materials lists produced incorporates a wide range of materials and components commonly used in transformers.

In all cases the user should confirm the suitability of any material to be used in equipment with MIDELE ester-based fluids. When investigating the compatibility of a material or product, ask the vendor or transformer manufacturer if they have run compatibility tests.

### For gaskets, MIDELE recommend good maintenance practices

By the time a transformer is identified as a retrofill candidate, it has most likely been in operation for several years. The condition of the gaskets likely includes wear and tear (swelling from contact with oil) and mechanically set (it has taken a 'set shape', dried out, cracked). If untouched, gaskets may survive without incident. However, during retrofill it is likely gaskets will be touched, either physically or indirectly.

If the tank and/or the gasket itself (in an aged, set, potentially cracked condition) is moved, the outcome is likely to be less than desirable. This has nothing to do with any interaction with the fluid, but rather the mechanical integrity of the gasket. The same recommendations would apply to a service company flushing, reprocessing or refilling with mineral oil. The outcome is not provoked by the new mineral oil; rather, it is because the aged gasket was directly or indirectly moved.

## Tap Changers and MIDEL fluids

MIDEL fluids are approved for use with a range of tap changers from industry leaders such as MR and ABB. For more information on tap changer compatibility, including other brands of tap changer, get in touch with Insulect's technical team.

## Transformer Components

Our technical team can answer any questions you have regarding compatibility of ester fluids with all transformer components – we've been a trusted component supplier to OEMs, end users and service businesses for over 30 years.

# #11 HV APPLICATIONS

## Can I use MIDEL fluids to retrofill transformers at high voltages?

**For retrofill, it depends upon the voltage and power rating.**

MIDEL fluids are approved for use at transmission voltage levels by several leading OEMs. MIDEL 7131 has been used for multiple projects at 400kV and in mobile test equipment up to 500kV. In common with other ester-based fluids, some design adjustment may be needed for higher voltage levels due differences in permittivity and dielectric performance.

Although MIDEL fluids are suitable for higher voltage levels in specifically designed transformers, retrofilling depends upon the voltage and power rating. As a general guideline the table below can be utilised.

DT/PT	kV	M&I Position
DT	< 33kV	No foreseen issues
PT	33-66kV	Review nameplate; evaluation recommended for helical winding designs, disc type windings, tap changers
PT	66-170kV	Verification of leads & winding assembly recommended, ideally including dielectric design. Possible modifications required
PT	>170kV	Applications should be considered R&D projects, requiring detailed design review and possible modifications

# #12 INTERFACIAL TENSION

## Is interfacial tension a meaningful property for MIDELE fluids?

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Interfacial Tension (IFT) is routinely used as an indicator of polar contaminants in mineral oil and can be directly related to oil condition.

**For ester-based fluids IFT is less sensitive to polar contaminants and not so useful for aging assessment.**

The reason is that ester-based fluids have a slightly polar molecular structure, giving them a lower IFT when new than mineral oil. The value of IFT is also less affected by polar contaminants and the difference between a new ester and an aged ester is smaller than it would be for mineral oil.

Currently none of the ester standards for synthetic or natural esters place specification limits on the value of IFT. [IEC 62961:2018](#) provides some guidance for measurement of IFT in both mineral oils and ester-based liquids, but so far acceptance limits for in-use liquids are not established.

M&I Materials recommends using acid value and dissipation factor for the monitoring of MIDELE fluids in service.

# #13 REUSABILITY

## Handling of used ester fluids

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Depending on their condition MIDEL fluids can be reprocessed and reclaimed using similar equipment and methods to mineral oil.

**High moisture content:** vacuum filtration or treatment with absorbents such as zeolites

**High acid value:** treatment with Fuller's Earth or similar absorbent material

In common with all natural ester liquids, if the viscosity of MIDEL eN 1204 has increased by more than 20% from the starting value then it cannot be reclaimed and should be sent for disposal – either through recycling or incineration for heat recovery.

Used MIDEL eN 1204 can be fed into recycling streams for other used vegetable oils, to produce products such as biodiesel, oils, lubricants and soaps.

Used MIDEL 7131 which cannot be reclaimed for transformer use can be utilised as a lubricant additive to mineral oil base stocks.

# #14 DE-RATING

## Will there will be any derating of a transformer by changing it from mineral oil to a MIDELE ester fluid?

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**Distribution transformers:** unlikely

**Power transformers:** an assessment may be required

**For distribution transformers** there is unlikely to be any need to de-rate the unit after retrofilling. Due to the higher viscosity of MIDELE fluids the transformer may run a few degrees hotter, but this is offset by the enhanced paper lifetime provided by an ester fluid.

**For transformers in excess of 66kV** a more in-depth assessment may be needed to determine the temperature rise change.

For example:

If the transformer specification reads '55 AWR' and the mineral oil filled unit was factory tested at 54 AWR, it may be the position of the manufacturer that the transformer would exceed the temperature rating.

However, this is more than offset by the slower paper aging and MIDELE's enhanced thermal capabilities. As indicated in [IEC 60076-14](#) and [IEEE C57.154](#) ester-based liquids can operate at a higher temperature than mineral oil for a given paper lifetime. Taking into account this slower paper aging, there is no need to de-rate a retrofilled distribution transformer, even if the operating temperature increases.

# #15 RETROFILL PROCESS

## Are there extra requirements or steps when retrofilling transformers with MIDEL fluids?

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There are four main steps to follow to retrofill transformers with ester fluids, as follows:

### 1. Set up retrofilling plant

- Follow site procedures
- Ensure transformer is fully de-energised and grounded
- Perform site inspection and complete safety handover

### 2. Reduce mineral oil content as much as possible

- Connect pumps and hoses
- Ensure all pumps, lines and hoses are bonded and earthed
- Pump the mineral oil from the transformer to the waste container
- Rinse core and windings with heated ester fluid
- Allow time for the tank to fully drain

### 3. Fill again using new ester fluid

- Use heated fluid
- Use dedicated hoses and pumps to prevent contamination

### 4. Test and nameplate

- Perform safety inspection and complete handover
- Take fluid sample to carry out appropriate testing
- Attached MIDEL nameplate as confirmation that the transformer has been retrofilled.

# Still got questions?

We hope our [Top 15 Questions on Retrofilling with ester fluids](#) has been helpful to you. If you've got other questions on retrofilling, or on MDEL ester fluids generally, we are more than happy to answer your questions.

Contact us on the details below, visit our website, or browse the MDEL brochures and datasheets, which summarise the key information on these products.

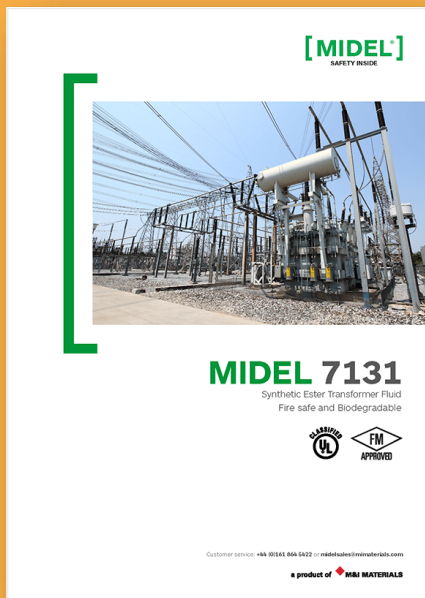
## Contact Insulect

Australia, New Zealand, Pacific.

1300 446 565

[sales@insulect.com](mailto:sales@insulect.com)

[insulect.com](http://insulect.com)



[Synthetic Ester Fluid](#)



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