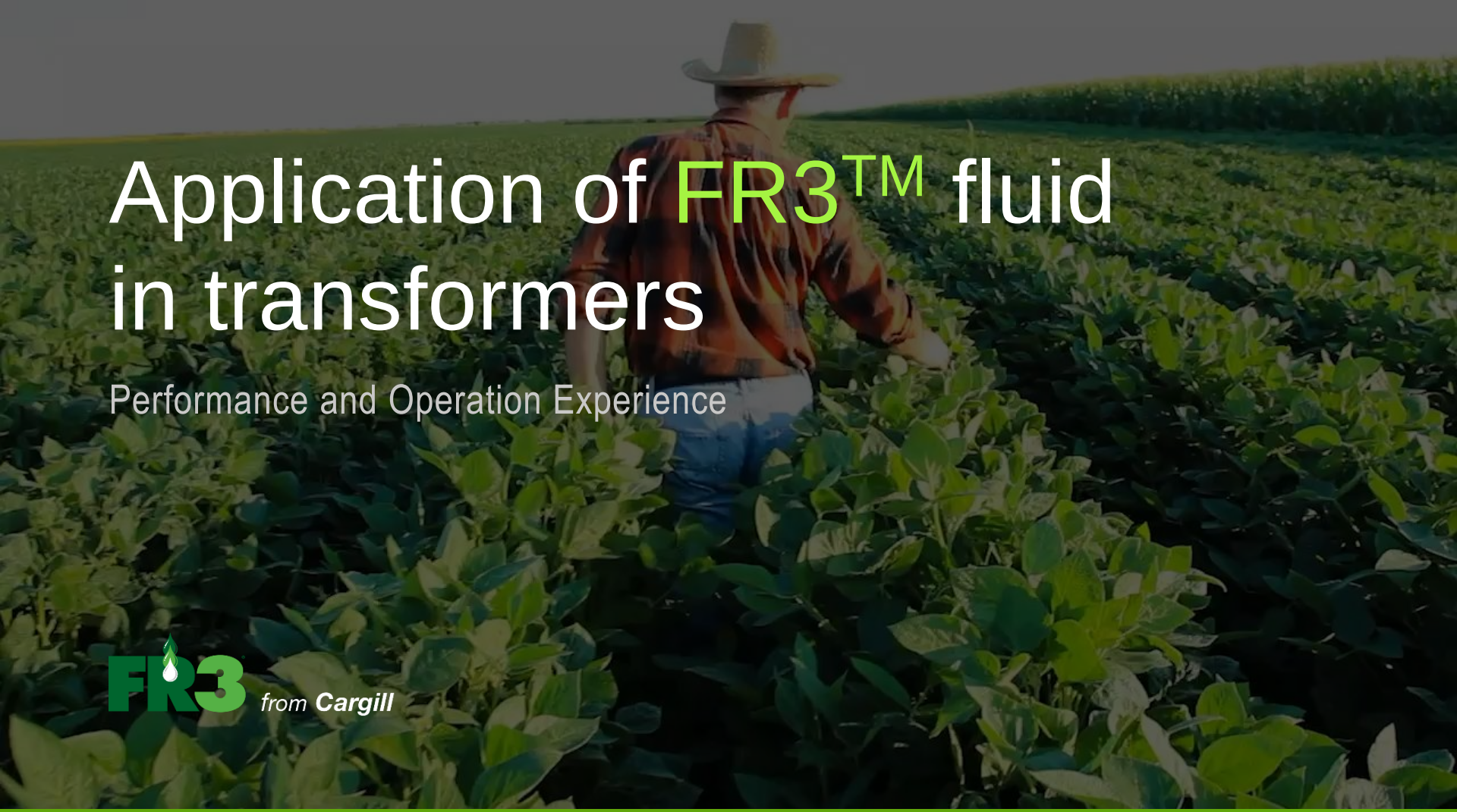

Application of FR3™ fluid in transformers

Performance and Operation Experience

FR3 from Cargill

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Advantages over mineral oil

Mineral oil

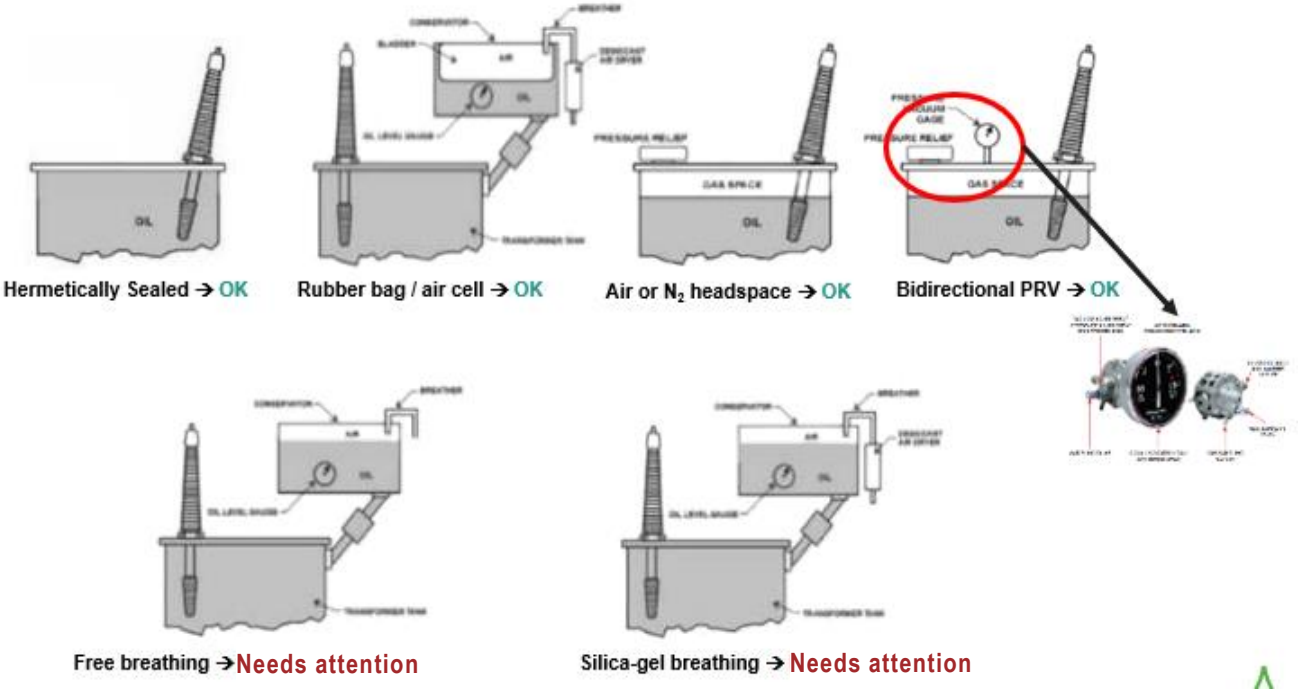
1. Risk of fires:
   - Flash point is less than 40°C higher than operating temperature limit
2. Low biodegradation rate
3. Low moisture saturation
   - Especially at low temperatures, dielectric capacity may be reduced / free water
4. Oxidation may lead to sludge formation, paper degradation and dielectric issues

Ester based fluids

1. Fire safety
   - Flash point is more than 2x the operating temperature limit
2. Readily biodegradable
3. Moisture saturation more than 10x higher
   - Keeps dielectric performance at very low temperatures
   - Reduces paper degradation rate
4. Very low sludge formation and, for natural esters, oxidation leads to increase of viscosity

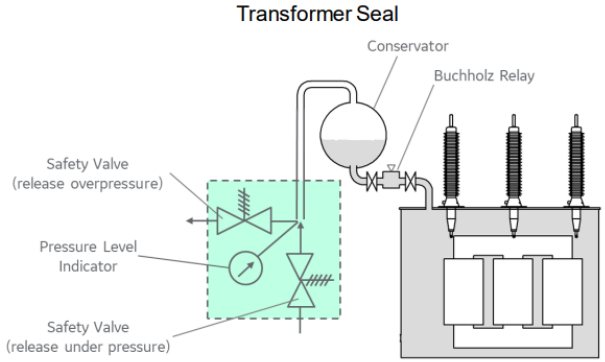
Recommended Configurations

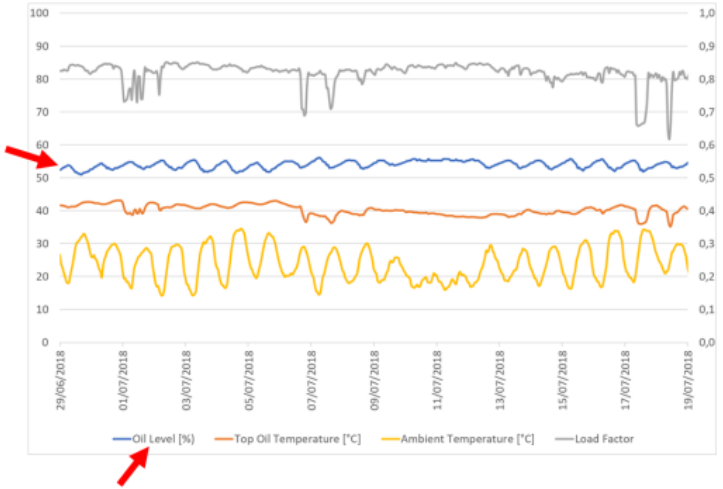
Some sealing system configurations need additional attention

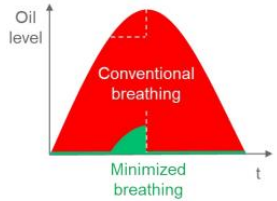


Recommended Configurations

Alternative Solution for non-free breathing power transformers







Advantages

- Reduction of transformer breathing
- Simple & robust mechanical solution
- Retrofittable

Dielectric Properties

Characteristics to be considered when designing a transformer

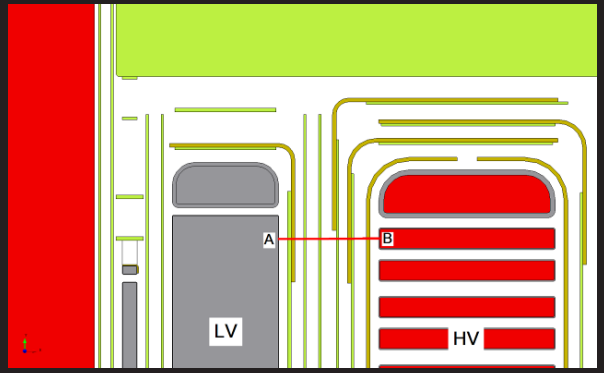
Dielectric insulation design

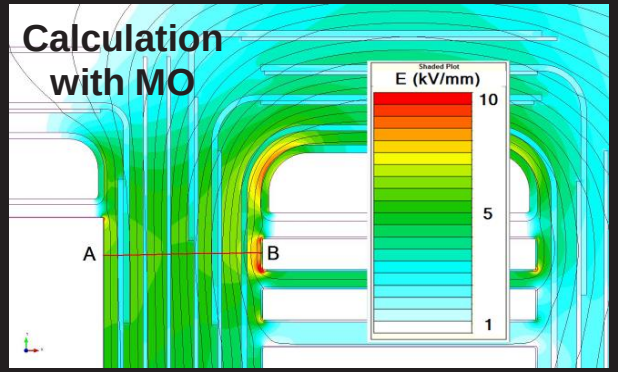
Important considerations

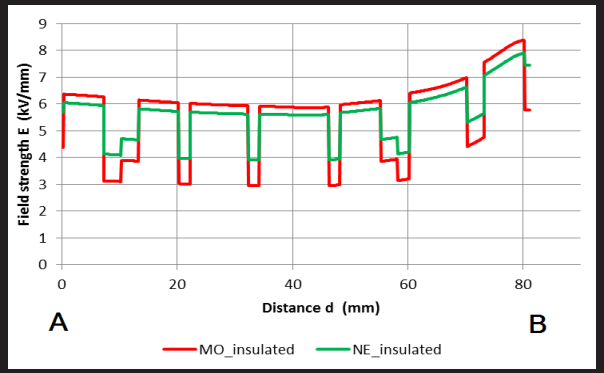
- The differences of permittivity affect electrical field distribution;
- Tendency to increase the stress at corners and edges;
- Attention to tangential creepage;
- The design MUST consider the properties of applied materials.

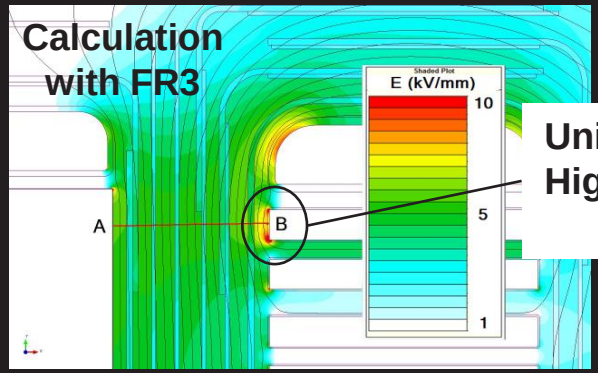
Relative Permittivity		
Material	Impregnated with MO	Impregnated with NE
Mineral Oil – MO (typical)	2.2	-
Natural Ester - NE (FR3 fluid)	-	3.2
Kraft Paper	3.2	3.4
Low density pressboard (TIII)	3.5	4.0
High density pressboard (TIV)	4.4	4.6

Main GAP Design



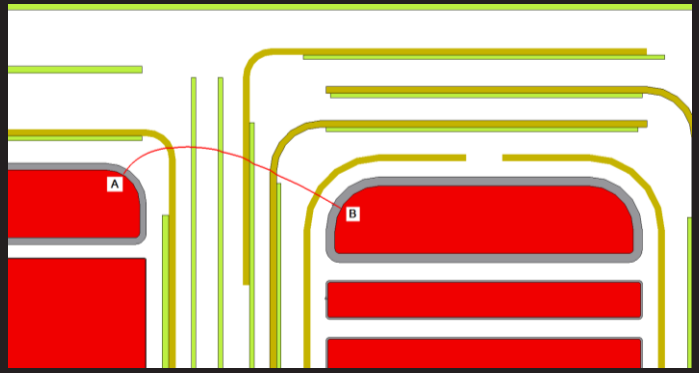


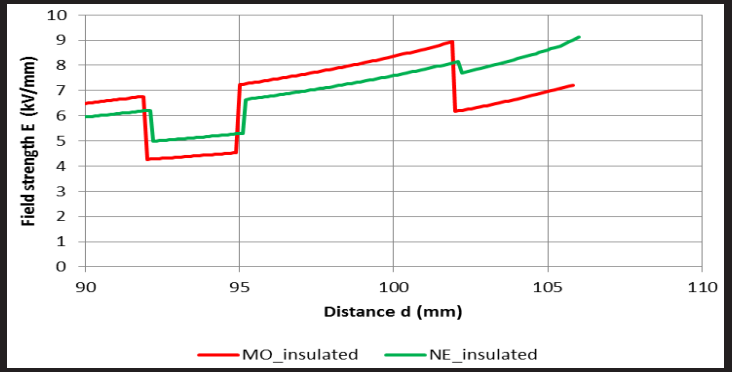


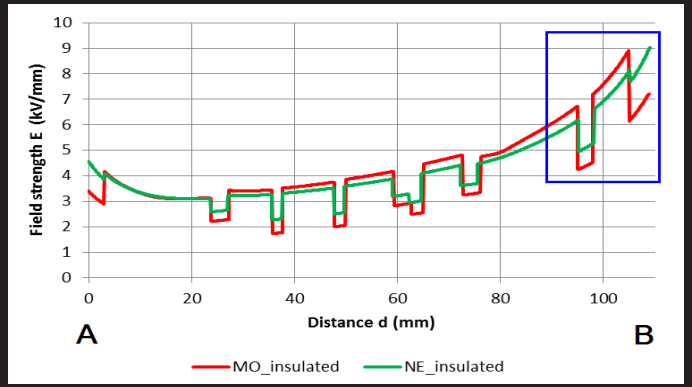


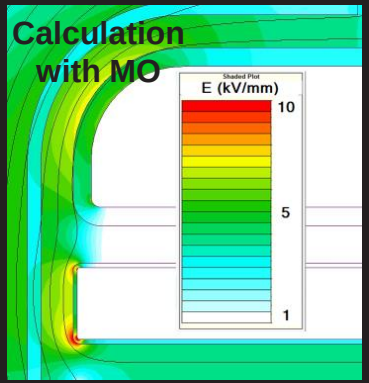
Uniform in the center
Higher concentration in the corners

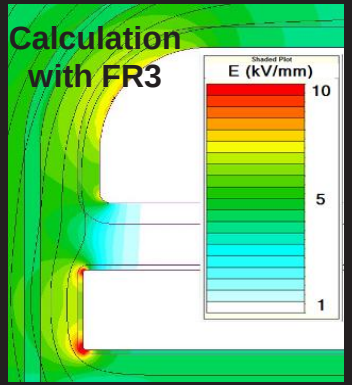
Main GAP Design





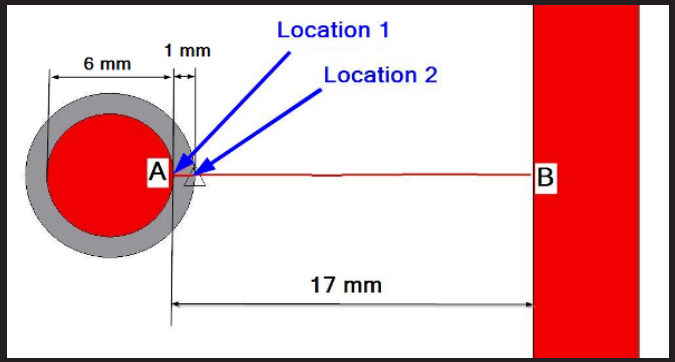


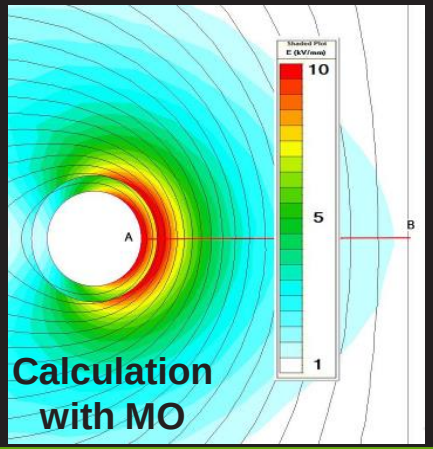


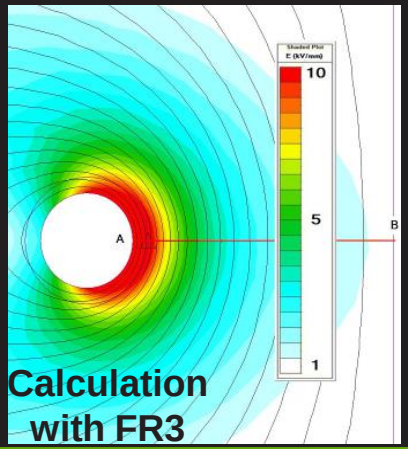


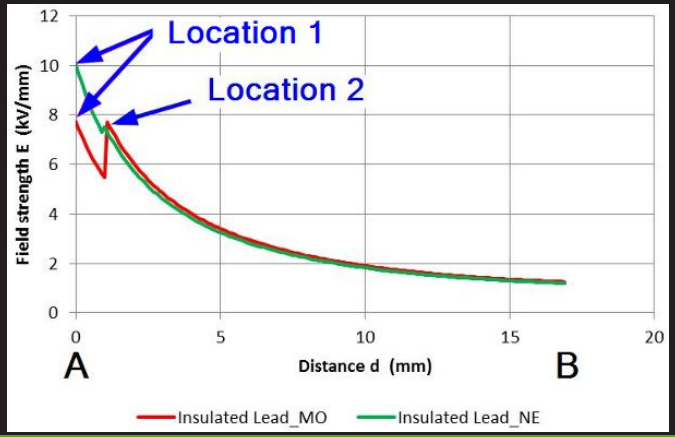
Differences on internal leads

- Solid insulation design is currently defined based in standard tables developed for MO
- Stress at the surface of solid insulation increases when immersed in NE
- It may be necessary to increase insulation thickness or gap between conductors



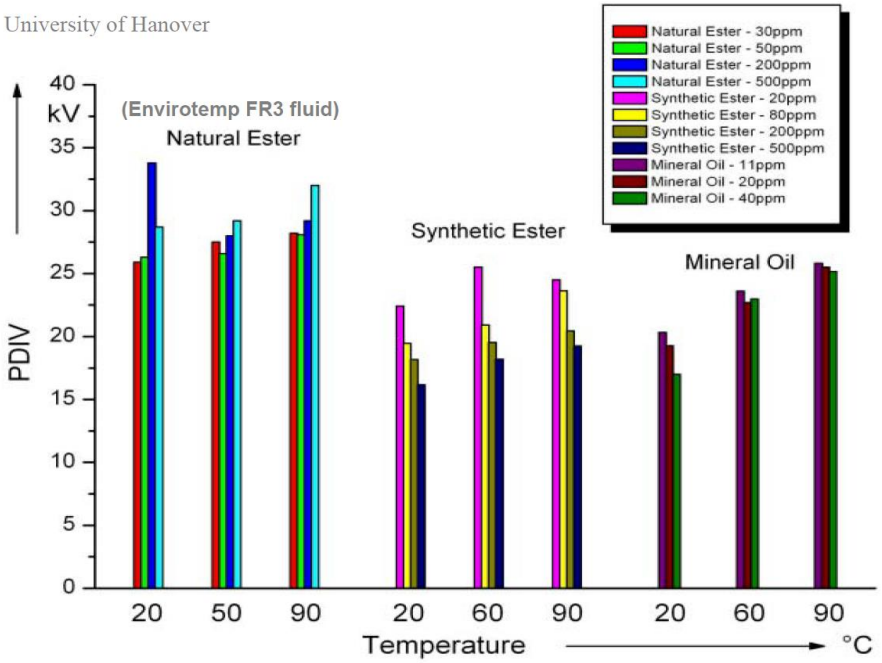






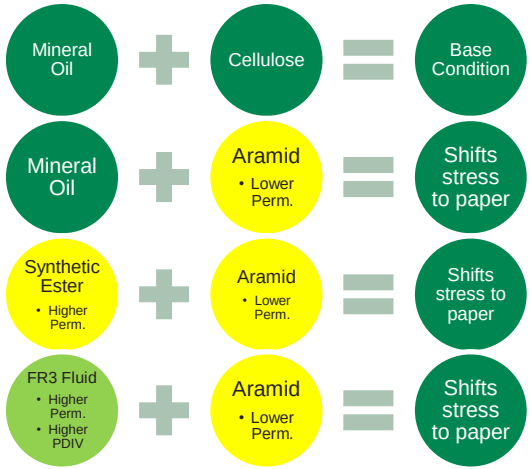
PDIV in FR3 Fluid

Studies show better performance than other fluids



10% higher than MO and SE

Studies show that FR3 fluid has a PDIV about 10% than from mineral oil and synthetic ester and that his is stable in different temperatures.



Concentration of stress around insulated corners of the windings. This MUST be taken in consideration during the design stage. But no additional measures versus SE.