

Green power needs the **green fluid.**

Take your wind turbines to a higher level by using FR3[®] fluid by Cargill to help make your transformers more compact and sustainable*, all at a lower cost than synthetic fluid filled and dry-type transformers.



*Compared to synthetic filled transformers.





As the demand for wind power rapidly grows and installations become larger and more advanced, it is essential to specify high-performing transformers that are compact and lightweight, but also progress the mission towards a more sustainable solution. FR3® fluid – the original natural ester transformer insulating fluid - is proven and validated with over a decade of use in wind turbine applications and nearly 30 years of power and distribution transformer applications.

The unique properties of plant-based FR3® fluid make it ideal for designing compact, maintenance free transformers for both onshore and offshore wind turbines. FR3® fluid not only helps provide superior performance in a more compact size, but also provides additional environmental benefits at a lower cost than synthetic fluid filled and dry-type transformers.





More sustainable

Contribute to your company's sustainability commitments while reducing dependency on fossil-based materials in your transformers by choosing FR3® fluid. Made from >95% vegetable oil, along with performance enhancing additives, FR3 fluid has many environmental advantages over other insulating fluids, including:

- Biodegradable in as little as 10 days
- Non-toxic in water, soil, and to wildlife and humans

Synthetic fluids cannot match FR3 fluid's biodegradability and dry-type transformers are not recyclable, making FR3 fluid the more sustainable* solution.

*Compared to other insulating fluids.

10

Biodegradable in as little as 10 days



Superior Fire Safety

FR3 fluid has exceptionally high flash and fire points - in fact, up to 50°C higher than even the leading synthetic fluids. This helps reduce the risk of explosion and fire—thus reducing the risk of damage to equipment and people. It is also a K-class fluid with FM Global and UL approval. Most impressively, there have been zero reported pool fires in transformers filled with FR3 fluid in over 25 years of use and over 3 million transformers filled globally.

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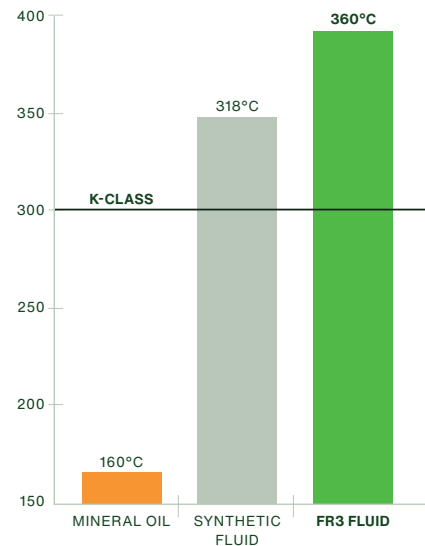
Reported fires in 25+ years

50°C

Up to 50°C higher flash and fire points*

*Compared to a synthetic fluid filled transformer.

Dielectric Fluid Fire Point Comparison





More compact with higher load capacity

Transformers designed to use FR3® fluid can be more compact and lighter weight than other transformer types while still maintaining a higher load capacity - critical considerations for wind turbines. FR3 fluid's unique properties allow transformers to safely operate up to 20°C warmer than a mineral oil filled transformer to gain up to 20% additional loading capacity, all without impacting the life of the transformer and without needing to use expensive aramid paper insulation. This allows for the design of a smaller, more compact transformer with the same loading capacity, the same sized transformer with up to 20% more loading capacity, or any combination in between*.

In addition to these benefits, FR3 fluid's unique moisture handling capabilities allows extended paper insulation life up to 4X longer compared to synthetic fluid, thus optimizing transformer size, loading capacity and extending transformer life to your specific application.

Dry-type transformers must be significantly larger to get the same amount of loading capacity compared to FR3 fluid filled transformers, making them difficult or sometimes impossible to fit in the nacelle of many wind turbines. Furthermore, dry-type transformers are already reaching the limits of the loading capacity they can provide and are unable to be used in many of the larger wind turbines being built today.

*Compared to a mineral oil filled transformer.

20%

Up to 20% more
loading capacity



Reduce costs

FR3® fluid is specially designed to help make transformers more compact, maintenance-free, and a more sustainable alternative, all at a lower cost than both synthetic fluid filled and dry-type transformers.

Synthetic fluid cannot match FR3 fluid's high flash and fire point or its sustainability benefits, but still costs up to 2X more. Dry-type transformers are larger, heavier and less efficient, while also costing up to 80% more than a FR3 fluid filled transformer.

FR3 fluid also allows for a Dual Rated/Sustainable Peak Loading rated transformer utilizing Kraft or TUK paper insulation, making FR3 fluid the smartest choice for both performance and cost savings.

50%

Save up to 50% versus
cost of synthetics



Maintenance free, more reliable

Onshore and offshore wind farms are often in remote locations that are difficult and expensive to access, making transformer maintenance costly and time consuming. FR3® fluid's unique moisture handling properties and high heat capabilities help allow for transformers that are maintenance free under normal operating conditions and also have improved reliability.*

Many transformer maintenance interventions involve removing moisture from a transformer's solid insulation and dielectric fluid. With FR3 fluid, this is often not required due to its high moisture saturation value and its unique "self-drying" mechanism that naturally absorbs moisture from paper insulation to keep it dry throughout the transformer's life without producing any damaging byproducts.

Synthetic fluid filled transformers tend to fail faster when an unexpected situation arises, with high acidity and dissipation factor limits being reached more quickly than with FR3 fluid, which could lead to unforeseen maintenance interventions or even transformer failure.

Dry-type transformers also have large drawbacks. According to IEC 60076-11, dry-type transformers should not be used in any place where ambient moisture is higher than 92%, making them a poor fit for offshore wind applications. Moisture can condense on the surface of the transformer and lead to a dangerous flashover. In addition, almost no assessment or maintenance can be performed on dry-type transformers and they may fail without warning.

Wind turbine transformers can also have widely varying load fluctuations and variations in the rotational speed of the blades and gearbox that lead to difficult to handle harmonics, with the result causing high heat in the transformer's coils and partial discharges in the core. FR3 fluid's unique formulation was developed to handle high load fluctuations and high heat, with a top fluid temperature that can safely operate at up to 140°C¹, which also makes the transformer less prone to a partial discharge.

*Compared to synthetic fluid filled and dry-type transformer.

¹According to IEC 60076-14 and IEEE C57-154.

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**No maintenance needed
under normal operating
conditions**

140°C

**Easily handles high heat
with 140°C¹ top fluid
temperature limit**

Wind Power FAQs

Do I need to worry about oxidation when using FR3® fluid?

No. FR3® fluid is designed to be a robust solution for use in non-free breathing transformers where it will last the complete lifespan of the transformer without the need of any maintenance. If there is a breach in the sealing system, FR3® fluid's oxidation is expected to require over 10 years to lead to a 10% increase in viscosity, and this will not negatively impact any characteristics of the fluid. The only effect will be the transformer running approximately 2°C hotter.

Under free breathing conditions for both natural and synthetic esters, the first maintenance limit to be surpassed is the allowable moisture content of the fluid. This may lead to a decrease in the breakdown voltage, which happens faster in synthetic fluids due to its higher moisture absorption and the lack of "self-drying" properties inherent to FR3® fluid. Also, acid content and dissipation factor maintenance limits will be reached in approximately 5 years, many years before any impact on viscosity due to oxidation is detected.

Can I refill existing transformers with FR3 fluid?

Yes, FR3 fluid can be used to refill both synthetic and mineral oil filled transformers. In fact, many wind turbine farm operators have been refilling synthetic-filled transformers with FR3 fluid in order to improve reliability and reduce maintenance. Both synthetic fluid and mineral oil have issues handling the difficult harmonics and varying load capacities in wind generation, which causes accelerated aging of the insulating fluid. FR3 fluid is specially formulated to handle high heat and challenging harmonics without accelerated aging of the fluid.

Is FR3 fluid miscible with synthetic fluid?

Yes, FR3 fluid is fully miscible with synthetic fluid. In a typical refill, Cargill would expect to see 3-5% residual fluid remaining, which does not impact FR3 fluid's performance.

Are there diagnostic tools available for FR3® fluid?

Yes. There is a complete set of standards from both the IEC and IEEE with guidelines for maintenance based on physical-chemical analysis. All the traditional DGA tools such as basic ratios, simplified ratios, and CO₂/CO can be used. Specific Duval Triangles and Pentagons for FR3 fluid are also available to perform a more accurate analysis of generated gases.

Can FR3 fluid be used in cold weather?

Yes, FR3® fluid is recommended for all non-free-breathing transformers, **regardless of ambient temperature.** FR3 fluid maintains breakdown voltage and the transformer's dielectric capacity down to -50°C (-58°F) and is qualified to be energized under normal operating conditions defined by IEC down to -25°C and IEEE down to -20°C.

For very cold climates, Cargill recommends using the same cold start procedures already defined by turbine manufacturers - start with a reduced load for a certain period of time and after, use a linear increase up to full load. This will allow for a smooth temperature increase on the transformer and will guarantee suitable fluid flow inside it.

How are larger wind turbines impacting transformer specifications?

As turbine blades grow well over 100 meters in length, more powerful transformers are needed to transmit all the power being generated. As transformers become larger, more insulating liquid is needed, and the insulating liquid becomes a larger portion of the overall cost of the project. FR3 fluid filled transformers can be built more compact while still maintaining a high loading capacity, all at a lower cost than synthetic fluids.

Dry-type transformers are becoming too large to fit in the nacelle or are already past the limits of how much capacity they can provide, making them a poor fit for today's large wind turbines.





Learn more about how FR3[®] fluid can make your transformers more compact, sustainable and higher performing at [FR3fluid.com](https://www.FR3fluid.com).