KINECTRICS

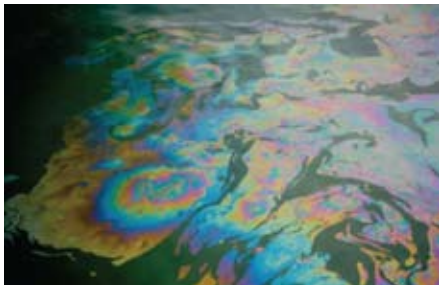
Anagen™

Self-healing & Repair Technology for Fluid-Filled Power Cables

FLUID FILLED CABLES – THE CHALLENGE

Fluid-filled and pipe cables were once common place before the advent of extruded polymeric cable technology. These older cables remain important operational assets that are difficult to replace economically. Because they are old, they are prone to leak with costly environmental and economic consequences.

- Present as legacy assets in North American & European networks
- Insulated with tightly wound paper and impregnated with low viscosity mineral oil
- To prevent void formation, cables are held under positive pressure (3-5 bar)
- Typically buried underground with difficult accessibility
- Where the cable sheath is damaged, oil leaks - a financial cost and environmental hazard
- Millions of litres of oil are lost annually from fluid cable networks



WHAT IS ANAGEN™?

ANAGEN™ is a new dielectric fluid for fluid filled cables (FFCs) that has been developed to mitigate fluid leakage from damaged cables to reduce the increasing operational and environmental costs associated with these ageing network assets. While ANAGEN™ can be handled and functions as a normal dielectric fluid, upon the development of a leak the fluid gels to form an impermeable barrier that **significantly reduces or eliminates the leak**. Moreover for more serious leak rates, ANAGEN™ will interact with cable backfill to form an oil-proof barrier, **limiting further loss of fluid and preventing further environmental contamination.**

Despite superior functionality, ANAGEN™ **does not sacrifice fluid or electrical properties.** Tests carried out by Kinectrics and large-scale cable oil suppliers have shown that the fluid possesses fluid and electrical properties similar to current mineral oils but with **improvements in breakdown strength.**

ADVANTAGES

- Autonomously resolves leaks of up to 40L / month, reducing costs associated with cable maintenance, oil replenishment, and environmental remediation.
- Capable of autonomously containing spillages and severe leaks within backfill materials, reducing contamination and the costs of remediation.
- Can be stored and handled as common cable dielectric fluids, with small changes in procedure to account for self-healing function.
- Equivalent or superior electrical properties to currently used mineral oils.

SELF-HEALING FUNCTIONALITY

ANAGEN™ is an air-activated self-healing dielectric fluid. Upon exposure to oxygen (either in open air or entrained within backfill or soils) the system forms a surface skin over the course of 20 minutes that is sufficiently strong to prevent further leakage.

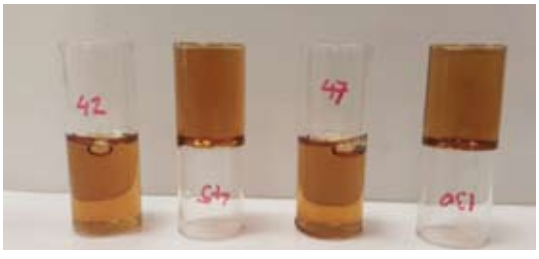


Figure 1. Demonstration of self-healing in exposed ANAGEN™. The sample is exposed to atmosphere and allowed to cure, after which skin strength is demonstrated by inverting the vial.

Curing is limited to the surface; there is no risk of this progressing back into the insulation system within the cable.

ANAGEN™ has been challenged using different fluid filed cable structures, either in open air or direct buried in backfill according to standard cable installation and operating procedures:

SELF-HEALING IN OPEN AIR

When testing ANAGEN™ under open air conditions, leak reductions of between 60-100% have been observed (see Figure 2) alongside a build-up of cured material in the leaked region. The maximum open air leak rate tested was 45L/month.

Figure 2. (Left) Leak / time chart for ANAGEN™ in open air showing complete leak cessation. (Right) Image following test completion showing build-up of cured material on leak site. Cable pressure constant at 30 PSI.

SELF-HEALING IN CONTAINMENT

In testing, the percolation rate for ANAGEN™ (defined as the period of time required to penetrate an equal depth of backfill) is much lower than that of LAB, meaning that a lower level of environmental contamination would be expected for an equivalent leak. In addition, conventional fluids reach an equilibrium and continue to leak, while ANAGEN™ rapidly self-limits to achieve complete containment.

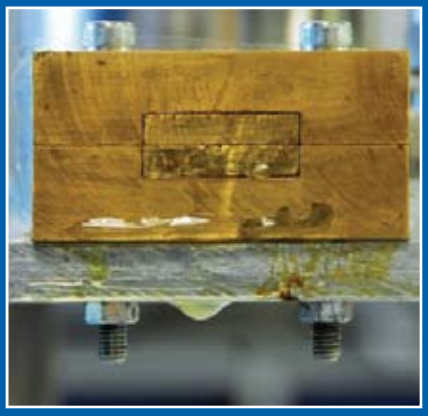
The synergistic interaction of ANAGEN™ and backfill is demonstrated by the condition of the backfill after treatment (see Figure 3). While backfill exposed to conventional cable fluids forms a loose crumb structure, ANAGEN™ treated backfill forms a hardened, cohesive material with oil-resistant barrier properties. During operation, it has been shown that this material prevents the flow of fluid, resulting in the oil-retardant and containment properties which protects the cable and the environment.

LAB ANAGEN™

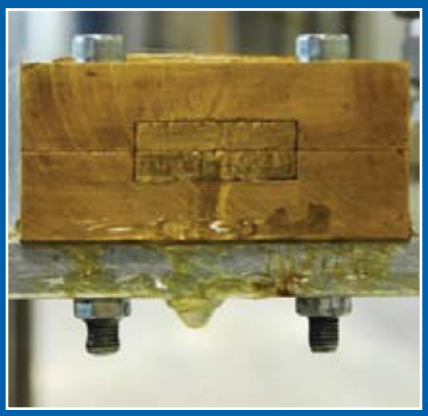
Figure 3. Samples of backfill exposed to (left)conventional LAB based dielectric fluid, and (right) ANAGEN™

REACTIVE PRINCIPLES

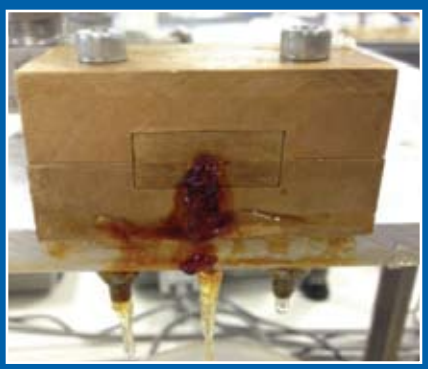
On exposure to oxygen, the catalysed SHF crosslinks to increase degree of polymerisation



Further crosslinking leads to surface gel formation, trapping the SHF within the asset



Gel strengthens and suppresses leak behaviour



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