Beyond the Limits of the Comparative Tracking Index

Testing Isolating Materials above 600 V

The voltage test of the comparative tracking index is limited to 600 V so far. In many areas the voltages increase, especially for electrical vehicles. Therefore, it is interesting to know what the real limits of isolating materials are. These are considerably higher. To test these, a modified test set-up is necessary.

Up to now, the test of the creep resistance only went up to 600 V. However, many insulation materials reach significantly higher values

(© Sergey Nivens, Adobe Stock)

The focus of the automotive industry is shifted more and more towards electrical vehicles and their development has speed up tremendously. One of the major challenges consists in increasing the driving range. Among others, it can be optimized through the car's efficiency. Therefore, the automotive manufacturers put their efforts towards higher voltages amongst others. Up to date electrical cars use battery voltage levels of 300 to 400 V_{DC} mostly. Recent examples like the Porsche Taycan take advantage of an 800 V battery. Next to higher voltages, also weight reduction and thus part »

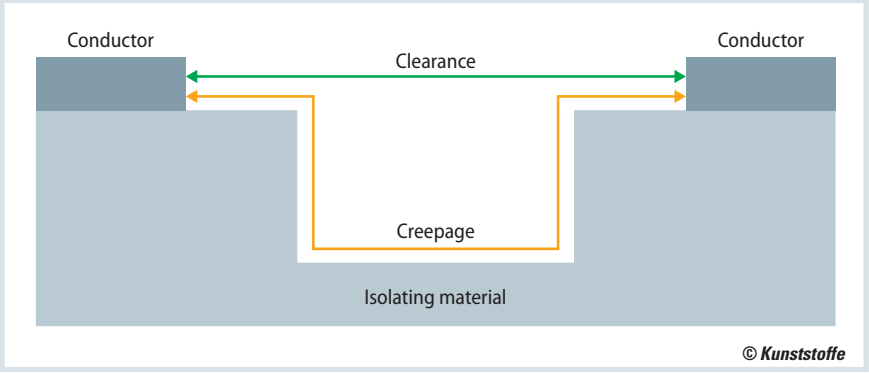


Fig. 1. The creepage distance, i.e. the shortest distance between two conductive parts along the surface, is usually longer than the air gap, the shortest distance between two conductive parts (source: Kuraray)

miniaturization lead to higher efficiency. Combining these two trends are, the demands on the insulating materials rise because failure caused by electric breakdown becomes a risk.

An Electrical breakdown generated by tracking (the base material is getting conductive) arise because of the formation of an electrical path due to degradation on the surface of an insulating material. For comparison and design reasons, a material's resistance against tracking is translated to its comparative tracking index (CTI). This is the highest voltage at which a material withstands 50 drops of an ammonia salt solution without tracking. A material with a high CTI owns a better resistance against tracking. Thus, enables to design parts with a smaller creepage distance (**Fig. 1**) – the minimum creepage distance are specified in IEC 60664–1 and depended on the CTI of the material.

To avoid excessive implied precision and bias, different performance level categories (PLC) were introduced (**Table 1**). The highest class "0" is indicating that no tracking occurs even at an impressed voltage of 600 V. Nowadays, more and more plastic materials are rated as PLC 0. Caused either by native properties such as polyphthalamides (PPA) or by additives to increase the tracking resistance as is realized with specific grades of polyphenylene sulphide (PPS) and polybutylene terephthalate (PBT). In the face of increasing voltages and continuous size-reduction, further improvements of materials beyond PLC 0 requirements become more interesting. Indeed, at this point the question pops up, which CTI actual materials have reached already: are 600 V the real limit?

The R&D department of the material producer Kuraray, Tokyo, Japan, dove deeper into this question. Therefore, the scientists started to evaluate Genestar PA 9T, a long chain PPA characterized by its low water absorption. It exhibits a CTI > 600 V and reaches therefore the PLC-class 0 for most of its unreinforced grades, and also for halogen-free V0 grades with 30 % glass-fiber (30 % GF) reinforcement.

Voltage [V]	PLC-class
>600	0
400–599	1
250–399	2
175–249	3
100–174	4
<100	5

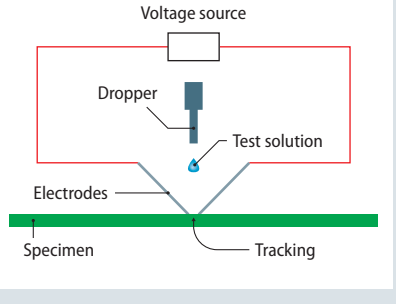
Table 1. Different PLC-classes according to the failure voltage (source: UL)

Standard Measurement Setup Prevents Tests

To find the limits of Genestar PA 9T, CTI measurements according to IEC 60112 were initiated (**see Box**) and the test voltage was ramped up to 625 V in a first attempt. Yet, it became clear that the upper limit of 600 V for current PLC-classes is most likely caused by the test setup itself. A partial breakdown over the air was visually observed (**Fig. 2, top**). This visual observation was confirmed as the over-current relay was tripped even though no tracking path was observed on the test piece. It was anticipated that this breakdown is caused by the edge of the electrode knowing that such an edge causes a higher field strength compared to a flat surface. To be able to execute measurements above 600 V the scientist turned the by 180°. This results in a higher clearance between the electrodes, therefore the electrode's edge is turned away while keeping the clearance at the test piece constant (**Fig. 2, bottom**).

CTI Measured According to IEC 60112

The measurement of the CTI requires a 3-mm thick sample that is subjected to a voltage, while one drop of test electrolyte solution (0.1 % ammonium chloride) falls every 30 s onto the sample surface. The test continues until either 50 drops fall or tracking occurs. Failure results if tracking occurs before 50 drops fall, generating enough current to trip the tester's built-in over-current relay. If the sample burns, the test is inconclusive and should be repeated using a thicker sample.



If a failure occurs, the voltage is typically decreased by 25 V and the test is repeated until a voltage is reached that the sample can pass. The passing voltage must be repeated for a total of five test sites on the sample. Additionally, the sample must also pass 100 drops at 25 V less than the original passing voltage. When all these conditions are met, a material group is determined for the insulating material based upon the passing voltage for the 50-drop test.

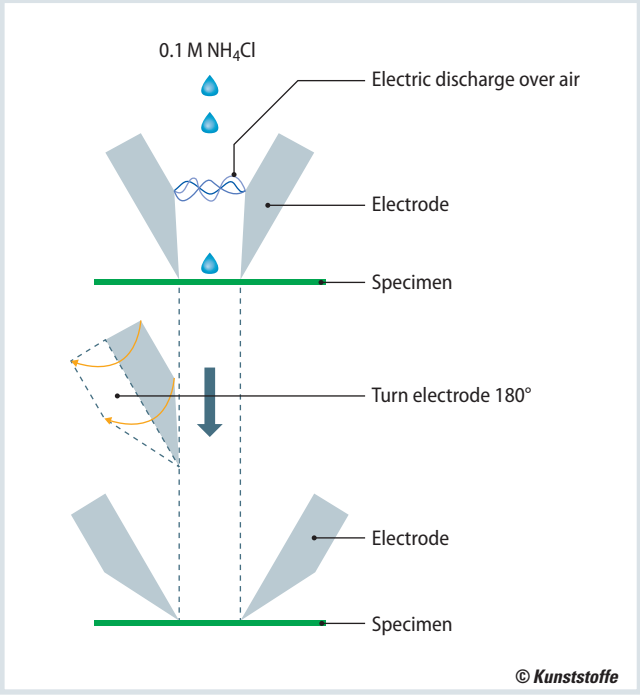


Fig. 2. At over 600 V, the measurement setup provided by the standard (above) causes a short circuit through the air. For this reason, the electrodes were turned by 180° for the tests
(source: Kuraray)

With this minor adaptation, the test voltage of the test setup could be ramped up to 750 V without a discharge over the air or influencing the measurement of the CTI. This was confirmed by a control measurement of a reinforced PPS type with a CTI of 550 V. Using this setup, five Genestar grades were evaluated with a test voltage up to 750 V (**Table 2**). For only two grades, a standard unreinforced one (N1000A-M41) and standard 30 % GF grade (G1300A-M41), tracking was observed at 675 V for the unreinforced material and at 725 V at the glass fiber-reinforced material. For the three other grades, which were developed for parts in the electrical environment, no tracking was observed, even not at 750 V.

Higher CTI thanks to Glass Fibers

Inorganic fillers like glass fibers seems to have a positive effect on the CTI, as all GF-reinforced grades show a higher tracking resistance. Like other ceramics, glass is a non-tracking material. The presence of glass-fibers act as an additional insulating layer that inhibits the formation of a conductive carbon path.

Also, for the unreinforced PPA grade, where tracking occurred at 675 V, the value is still well above the necessary 600 V for reaching the highest PLC rating. Considering its higher ductility, an excellent resistance against heat shock cracking can be foreseen, which makes such an unreinforced grade a perfect candidate for over molding of metal parts.

The test set-up in use allows measurements up to 750 V, only. The real limits of the other threes grades cannot be determined. However, these experiments show that the material offers protection against short cuts even at clearly higher tested maximum voltages and beyond. Anyway, for three of the investigated Genestar grades no tracking was observed even at a voltage of 150 V higher than the current limit.

Further tests are scheduled at the research and development center of Kuraray. The test set-up will be modified in that way, to be able to execute measurements up to 1000 V. From voltages >400 V, the surface of an isolating material become extremely important. The occurrence of surface-based tracking leads to untimely failure of parts, modules and systems in passenger cars. Due to the increasing voltages the CTI becomes a higher significance, especially for electrified cars. ■

Genestar grade	Product description	Breakdown voltage [V]
N1000A-M41	Standard, unreinforced	675
G1300A-M41	Standard, 30 % GF	725
G1300A-M42	E-friendly, 30 % GF	>750
GP2300S	Halogen-free, V0, 30 % GF	>750
GP2450NH-2	Halogen-free, V0, 45 % GF	>750

Table 2. Overview of the Genestar types tested: three of them show no tracking even at 750 V
(source: Kuraray)

The Authors

Dr. Wim Denissen is Market Development Engineer at Eval Europe N.V.
Shimon Kanai works as R&D Engineer at Kuraray Co., Ltd.
Dr. Naoto Sugai is R&D Engineer at Kuraray Co., Ltd.
Andreas Weinmann works as Business Development Manager at Kuraray Europe GmbH.

Company Profile

Kuraray was founded 1926 at Japan and is a global acting specialty chemicals company, head quartered at Tokyo. Kuraray is on of the biggest providers for polymers and synthetical micro fibers and is internationally leading in development and application of high performance materials, like Genestar PA 9T. The Kuraray group achieved a turn over of more than EUR 4.8 bn (FY2018) and employs more than 10,000 people.

Service

Digital Version

↘ A PDF file of the article can be found at *www.kunststoffe-international.com/2020–1*

German Version

↘ Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*