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Certification of electrical insulation systems acc. to UL standard 1446 Ed.8

Guidelines of the Electrical Winding & Insulation Systems Section

German Electro and Digital Industry Association

Contents

1 Introduction

In the course of globalisation and worldwide trade, the certification of products from the German electrical industry is playing an increasingly important role. Today, only safe products, i.e. products that have been tested and certified by recognized testing and certification institutes, find buyers on the global market.

Underwriters Laboratories

One of the most widely used test marks is the American UL mark. It is often required for products that are to be sold on the North American market. The mark is issued by Underwriters Laboratories LLC. (UL), founded in 1894 and based in Northbrook (Illinois). UL performs similar tasks to VDE or TÜV.

UL is a leading organization in the USA in the field of electrical safety. Various product standards cover the entire spectrum of electrical and electronic products and applications.

If you compare the safety philosophies between the VDE and UL, you will very quickly notice serious differences: While the VDE focuses on the individual component in the tests, UL focuses on the overall system in the tests.

Edition 7 of the UL 1446 standard, published in November 2016, brought some innovations and more clarity to the certification process for electrical insulation systems (EIS) at UL. The scope of the standard for EIS, for which thermal stress is the decisive factor for ageing, has remained unchanged from the previous versions 1-6. (UL1446 Editions 1 to 6 focused on consumer products, i.e. applications operating in the voltage range below 1 kV, and the American market).

What is new, however, is that IEC (International Electrotechnical Commission) standards are preferred for testing. The previously common North American ASTM (American Society for Testing and Materials) standards are listed as technically equivalent. Furthermore, UL1446 Ed.7 focused on the thermal evaluation and classification of EIS independent of the operating voltage. UL 1446 Ed.7 referred for the first time to IEC 61857-2: "Electrical insulating systems - Methods of thermal evaluation - Part 2: Selection of the appropriate test method for the evaluation and classification of electrical insulating systems".

This change makes it much easier to understand how the requirements for insulating materials - depending on their intended use - are to be understood. The new structure also enables direct access to the relevant section of the standard.

Edition 8 has been valid since November 2019, which refers to the latest ANSI and SCC approval data and requirements for thermal ageing testing with a defined service life. The corresponding test method is described in this brochure.

The updated version of UL 1446 Ed.8 provides a user-friendly, harmonized and practicable standard.

Please note that the information in this document represents the views of ZVEI and does not necessarily reflect the position, strategy or opinion of UL LLC.

2 How is UL 1446 to be understood?

The UL 1446 standard is a mixture of administrative specifications relating to the creation and expansion of electrical insulation systems and the description of corresponding test procedures.

A key component is Table 1, which classifies system components into electrical insulation materials (EIM) and materials not used as electrical insulation (NIM) and is therefore the specification for the resulting test requirements for the individual materials.

An informative appendix on the substitution of enamelled wire with the designation of IEC types -rounds off the standard.

In this respect, the UL 1446 standard is a general guideline for the creation and expansion of electrical insulation systems.

3 Reliability of electrical equipment

The condition of electrical equipment is crucial for safe operation. High reliability, good efficiency, low probability of failure and low maintenance costs are decisive factors in the use of equipment today. A decisive parameter here is the ageing behaviour caused by the load on the system.

Here, we can distinguish between

- electrical aging
  (creepage currents, partial discharges or interface processes),
- chemical aging
  (chemical incompatibility, e.g. plasticizer outgassing, degradation),
- thermal aging
  (diffusion or also thermo-mechanical alternating stress, substance degradation),
- mechanical aging
  (vibrations and shock loads, infiltration, abrasion) and
- environmental aging
  (UV radiation, weathering, salt spray)

Electrical ageing is based on physical processes such as leakage currents, partial discharges or interface processes. The ageing function, i.e. the dependence of the service life on the load, follows an (empirically determined) inverse service lifetime law

$$L_{el} \sim E^{-nt}$$

where E is the electrical load, n is the life duration exponent and t is the time.

Thermal ageing, on the other hand, is more likely to be caused by chemical and/or physical processes such as curing, polymerization, diffusion or thermo-mechanical stress. The mathematical dependency here follows an exponential law similar to the Arrhenius equation, which is a measure of the reaction kinetics of chemical processes as a function of temperature:

$$L_{th} \sim A \cdot e^{-m/T}$$

with m as the lifetime exponent and T the absolute temperature.

A rule of thumb says that an increase in the operating temperature of 10°C corresponds to a halving of the service life.

The mechanisms of ageing can be intrinsic or extrinsic. A temporary deterioration in the condition of the equipment is referred to as degradation, a permanent deterioration as deterioration.

The ageing mechanisms listed lead to a weakening of the insulation materials, which determine the electrical operating safety. In the worst case, this can lead to a dangerous operating situation (fire hazard, risk of electric shock).

The sum of all electrical insulation materials (EIMs) in a device is referred to as the EIS (Electrical Insulation System) and is often highly customized in terms of design and application. The reliability of the EIS depends on the compatibility of the EIM materials with each other and thus their reaction as a system. UL 1446 covers the guidelines and test methods for evaluating the thermal performance of insulating materials and their interaction as a complete system under thermal load.

4 Structure and components of an electrical insulation system

The operational reliability and durability of wound products are closely linked to the insulation technology used. The temperatures possible during operation can lead to chemical reactions with signs of ageing, combined with weakening of the material, and thus to dangerous operating situations (such as fire, risk of contact with live parts).

Winding goods themselves consist of a variety of components. The coil(s) made of winding wire (enamelled copper wires, covered wires, etc.) and the permeable core (electrical sheet, ferrite core, etc.) are the functional components. In most cases, the winding material is built up on a winding body with insulating intermediate layers.

The winding itself must be constructed in such a way that protection against contact with live parts and protection against ignition at operating temperature is provided. Components such as surface insulating materials, the impregnating varnishes/resins, the lead wires, the insulating hoses, but also the potting compound that may be used serve to ensure safe handling and operation.

The reliable joint interaction of all components made of electrical insulation materials (EIM) in an electrical insulation system (EIS) is a given with a UL-certified system. The basis for this is the UL standard UL 1446 (Standard for Safety for Systems of Insulation Materials - General).

Underwriter Laborities (UL) distinguishes in principle between system components that are used as electrically insulating materials (EIM) and materials that are not used for electrical insulation (NIM).[1]

[1] Note: the previous designations Major and Minor Components are no longer used. For more information, see section 5 Table 1.

5 UL certification of the electrical insulation system

There are two categories of electrical insulation systems: The first category is referred to as "Systems, Electrical Insulation - Components (OBJY2)" and includes a UL recognized EIS for a specific motor or transformer, for example. The second category, "Component - Electrical Insulation System Components (OBJS2)", is intended for incorporation into a third-party application, is listed in the iQ Electrical Insulation System Database and is made available to customers by major manufacturers.

Each EIS to be certified in turn consists of a large number of individual electrical insulating materials, which are divided into a) components with an insulating function (EIM) and b) components whose task is not primarily an insulating function (NIM). The differentiation is based on the assumption that components with an insulating function are of particular importance for the protective effect with regard to electrical safety and fire behaviour, i.e. they represent the insulating barrier between the various electrical potentials. In contrast, the other components (NIM) are mainly used for non-electrical purposes, i.e. in the broadest sense for physical (mechanical) reasons such as strength or absorption of thermal or mechanical stress. Components with an insulating function are referred to in German as primary insulation.

Function	Description	Component
Electrical insulation function EIM	Components whose failure would result in a serious loss of safety	Enameled copper wire Coil former Surface insulating material impregnating agent[2]
Other function NIM	Components whose failure does not result in a significant loss of safety (typically those used for thermal or mechanical connection)	Lead wires Insulating hoses Layer insulating materials Wrapping tapes Potting compounds

Table 1: Examples of important components

For further examples and an overview, see UL 1446-Ed.7 Table 4.1

Note: Certification for the Canadian market can be applied for during the project phase, before testing begins.

[2] Impregnating agents are classified as components with an insulating function if they were also tested in the original Full Thermal Aging Test and have influenced the overall performance of the system. Otherwise, they are classified as components with a non-insulating function and must be included via a compatibility test (see 5.2).

5.1 Full Thermal Aging Test (FTA)

In order to obtain recognition as a UL Recognized[3] Insulation System, a so-called "Full Thermal Aging (FTA) Test Program" is required. For the adaptation of an already certified system, the so-called compatibility test CCT (Chemical Compatibility Testing), also known as Sealed Tube Testing, may be sufficient.

A test setup described in IEC 61857-21 is required for UL recognition of an EIS in accordance with UL 1446. This test setup, the so-called general purpose model (GPM), is also known colloquially as a motorette (simplified model of a motor). To determine the temperature class up to which an EIS may be used, the GPM models are aged at at least three different temperatures.

System class	Max. Peak temperature [°C]
120 (E)	120
130 (B)	130
155 (F)	155
180 (H)	180
200 (N)	200
220 (R)	220
240 (S)	240
Over 240 (C)	over 240

Table 2: System classes according to UL 1446 For further details see also IEC 61857-1

Secondary components (insulating materials without electrical insulation task; NIM) can, but do not have to, be part of the test. They can be subsequently supplemented by shortened tests such as the CCT test (sealed tube test).

The aim of the voltage tests is to determine how strongly the dielectric strength of the components depends on ageing under thermal load. The test is considered passed if the dielectric strength of the insulation material still has a dielectric strength of 600 V_{eff} (phase-phase and phase-ground) or 120 V_{eff} (winding-winding) at the end of each test cycle (see temperature stress tests in the following table).

The test must be carried out at at least 3 different temperatures in order to provide a reliable estimate of the appropriate temperature class.

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[3] UL uses the term "certification" to refer to the process of evaluation according to the appropriate standard. UL uses two additional terms to distinguish between a ready-to-use product and a component/item that is expected to be used in the manufacture of a product.

Listed: *This designation is used for ready-to-use products such as appliances, computers, fans, pump systems, power tools and all other finished goods.*

Recognized: *This term is used for all components of any kind that are not expected to be used alone, but as components of some kind in a ready-to-use product. This includes actual components as well as technical information, such as the report on the evaluation and classification of a material or an EIS.*

The following table shows the ageing cycles of the various test sequences:

First the UL 1446 test cycle:

Test cycle UL 1446	Implementation	
Temperature test (ageing)	Highest temperature: Next lower temperature: Next lower temperature: Lowest temperature:	24 - 72 hour cycle 48 - 168 hour cycle 96 - 336 hour cycle 168 - 672 hour cycle

Table 3: Test cycle UL 1446

This compares with the IEC 61857 test cycle:

Test cycle IEC 61857-1	Implementation	
Temperature test (ageing)	Highest temperature: Next lowest temperature: Lowest temperature:	24 - 72 hour cycle 48 - 336 hour cycle 504 - 840 hour cycle

Table 4: Test cycle IEC 61857-1

At least 10 multi-purpose models (GPM) are required for each temperature. The temperatures to be applied depend on the desired heat class and the possibilities of loading the materials beyond the desired heat class. For example, a 180(H) system can be tested at 200°C, 220°C and 240°C.

Illustration 1Test procedure FTA, image source Synflex

The typical procedure for an insulation system approval of a completely new EIS is as follows:

1.) Complete aging test (FTA)

2.) Addition of secondary components and also main components (taking into account the specifications according to UL 1446) by Sealed Tube Test (CCT))

3.) Use of the EIS in the end application

It usually takes around a year of testing before a completely new EIS is approved, in addition to the project preparation.

5.2 Compatibility test CCT test (Sealed Tube Chemical Compatibility Test)

As an alternative to a time-consuming complete ageing test, many users use the option of adding the desired components without insulation function (NIM) to existing EIS by means of a compatibility test. This is described in IEC 61858 Annex B. It must be emphasized that it is only possible to add or replace components with insulation function (EIM) to an existing EIS to a limited extent. Permissible changes to an insulation system are described in IEC 61858. However, enamelled copper wires can be supplemented / replaced in accordance with the conditions in UL 1446 or IEC 61858 Annex A.

The compatibility test is a standardized procedure that tests the chemical compatibility of the main insulation materials with regard to the interactions with the added secondary components (e. g. insulating sleeves, insulating materials, adhesive tapes, stranded wires, casting compounds, cords, etc.).

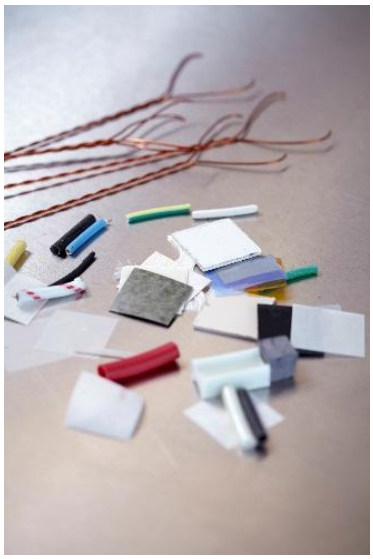

Illustration 2+3: Glass flask (sealed tube) and heating cabinet (Synflex images)

The focus is on the electrical strength of the enamel-insulated wires. This is determined after all components of the EIS have been stored together for 14 days in an airtight glass flask (sealed tube). Ageing takes place at the desired thermal class temperature, plus 25°C. As a reference, another airtight glass flask (sealed tube) is filled with only the components of the original EIS and aged in the same way.

The modified EIS is approved if the dielectric strength of the winding wires reaches at least 50% of the winding wires of the reference tube after appropriate ageing. Once the sealed tube test has been carried out, the modified EIS can be used after registration with UL.

Preparatory work: If you have found an OBJS2 system (i.e. an already known, tested EIS) that can be adapted to your own requirements by modification, it is necessary to contact the "owner" of the OBJS2 system. He must send UL a so-called "authorization letter". By means of this release, the owner of the OBJS2 system allows the desired modification and at the same time discloses all components in the original EIS. The submitter can then use this information to compile the sample materials for the CCT.

Based on UL's experience, it is possible to categorize electrical insulating tapes into so-called matrices. The idea here is that many adhesive tapes from one manufacturer differ only in terms of thickness, colour or transparency. However, the chemical structure is identical, so that no different influence on the winding wires in the sealed tube test is to be expected. In consultation with UL, the number of adhesive tapes to be submitted can be reduced in this way.

A CCT is a way to expand the list of acceptable materials after an FTA or in an existing EIS system without waiting for a full FTA. This assessment takes approximately 4-8 weeks, subject to material availability.

It is the responsibility of the submitter to provide all the necessary components for the sealed tube test. The final approval is documented in a so-called UL file. UL has developed a database in which the results of tested and approved EIS can be found (www.ul.com/iq).

5.3 Takeover of an existing EIS

The quickest, most cost-effective method of defining your own EIS is to adopt an existing EIS without any modifications.

As it is not necessary to use all the components of such an EIS, the user selects an EIS that contains all the required components.

There are two possible ways to transfer an existing EIS:

- The electronic copy transfers all data from the existing EIS to the customer's own EIS.
- The new EIS is included in the customer's follow-up service (quality control).

Separate permission from the current owner of the original EIS is required in the form of an "Authorization Letter".

Modifications are possible when taking over an existing EIS:

The modification must always be coordinated with UL. The similarity of two products is determined by comparing the IR spectra. This IR analysis is carried out exclusively by UL. If there is sufficient similarity, the products can be supplemented without further tests after approval by UL.

5.4 Further specific UL approval procedures for insulating materials

In addition to the full thermal aging test (FTA), there are other special test programs such as DLTA and STTA: DLTA and STTA.

5.4.1 Defined Life Thermal Aging (DLTA)

DLTA is a thermal ageing test for a defined service life of the electrical insulation system.

The DLTA program is intended for insulation systems used in applications where the intended operational life is 5,000 hours or less. This certification program is an alternative to the full thermal ageing program and is used to evaluate an EIS with a service life of 1500, 2500, 4000 or 5000 hours.

It requires fewer samples and less testing time compared to conventional full thermal ageing. The test requirements are contained in IEC 61857 Part 31 "Applications with a service life of 5 000 h or less".

Once a DLTA program has been completed, a CCT project can be opened to optimize the system.

With the help of the CCT test, NIM materials in particular can be added to an existing EIS under certain conditions. In the CCT test, the chemical interaction of all components of the extended EIS is tested at elevated temperatures. The assessment criterion is the dielectric strength of the twisted enamelled wire in the test specimen (twisted pairs, see also 5.2).

5.4.2 Short Term Thermal Aging (STTA)

STTA is a short-term thermal ageing test for electric motors.

The STTA program is a new service that evaluates an electrical insulation system for motors in low-voltage applications (≤ 1000 volts) is evaluated.

The Short-Term Thermal Aging (STTA) test for motors was specifically developed to accelerate time to market for customers in accordance with the UL 1004 series "Rotating Electrical Machines". The test requirements are contained in ANSI/UL/IEC 60335-1 Annex C and include an aging process of six production motors at elevated temperatures and humidity. Compliance with the requirements is determined by an electrical test (fault current and electrical strength).

The test time, which is determined from the desired temperature class and corresponding temperature increase, is listed below.

Test time	Temperature increase to the desired temperature class
1000h	40°C
2000h	30°C
4000 h	20°C
8000 h	10°C

Table 5: Temperature increase to the desired temperature class at different test times

Preferred patterns

- Small size (NEMA 56 frame or smaller)
- High resistance motors

Advantages of the program

- Shorter time to market due to short evaluation time (approx. 3 months)
- Low sample build-up thus cost and time savings compared to the current engine test program.

Approval / Classification

STTA assessment results are engine design and type specific and offer limited flexibility in material sourcing and end-use options compared to the traditional FTA program. Engines that go through this program are reviewed every three years to ensure that deviations in engine manufacturing processes have not affected the performance of the EIS.

A positive STTA test results in UL category OBJY3 for use in motor constructions according to the UL 1004 series standard (Electrical Rotating Machinery). Systems that fulfill the requirement according to IEC 60335-1 Annex C receive a System Certification Report that describes which insulation materials were used for the evaluation. The insulation system can be used for other motors of the same series, taking into account the identical insulation materials.

Important: A maximum of 2 EIM materials (electrically insulating materials), formerly known as "major components", can be tested and installed.

A CCT project can also be carried out according to an STTA, but is limited to NIM (non-electrical insulating materials), such as tapes, hoses, cable ties, leads and cords (see also 5.2).

More complex materials (e.g. film laminates, lacquers, potting compounds and impregnating resins) must be evaluated by an additional STTA or FTA program.

The material inspection takes place during the (follow-up) inspections carried out by UL on site (at the production location).

5.5 Test standards and evaluation procedures

There are various ways to generate or modify an electrical insulation system. The test standards used for this are described in the following table. The IEC is used as the preferred test method. If no IEC standards are available, the ASTM or IEEE standards are used.

ASTM Standards
ASTM D1676, Standard Test Methods for Film-Insulated Magnet Wire
ASTM D2307, Standard Test Method for Thermal Endurance of Film-Insulated Round Magnet Wire
ASTM D2519, Standard Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test
ASTM D3145, Standard Test Method for Thermal Endurance of Electrical Insulating Varnishes by the Helical Coil Method
ASTM D3251, Standard Test Method for Thermal Endurance Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire

ASTM D5642, Standard Test Method for Sealed Tube Chemical Compatibility Test
ASTM E178, Standard Practice for Dealing with Outlying Observations

IEC Standards
IEC 60172, Test Procedure for the Determination of the Temperature Index of Enamelled and Tape Wrapped Winding Wires [ASTM D2307, Standard Test Method for Thermal Endurance of Film-Insulated Round Magnet Wire].
IEC 60317, Specifications for Particular Types of Winding Wires (all parts) [ASTM D1676, Standard Test Methods for Film-Insulated Magnet Wire].
IEC 60455-2, Resin Based Reactive Compounds Used for Electrical Insulation - Part 2: Methods of Test
IEC 60455-3, Resin Based Reactive Compounds Used for Electrical Insulation Part 3: Specifications for Individual Materials (all sheets for individual resins) [ASTM D3251, Standard Test Method for Thermal Endurance Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire].
IEC 60493-1, Guide for the Statistical Analysis of Ageing Test Data - Part 1: Methods Based on Mean Values of Normally Distributed Test Results
IEC TR 60493-2, Guide for the Statistical Analysis of Ageing Test Data - Part 2: Validation of Procedures for Statistical Analysis of Censored Normally Distributed Data [ASTM E178, Standard Practice for Dealing with Outlying Observations].
IEC 60505, Evaluation and Qualification of Electrical Insulation Systems
IEC 60851, Winding Wires - Test Method (all parts)
IEC 61033, Test Methods for the Determination of Bond Strength of Impregnating Agents to an Enamelled Wire Substrate [ASTM D2519, Standard Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test]
IEC 61857, Electrical Insulation Systems - Procedures for Thermal Evaluation (all parts)
IEC 61858-1, Electrical Insulation Systems - Thermal Evaluation of Modifications to an Established Electrical Insulation System (EIS) - Part 1: Wire-Wound Winding EIS [ASTM D5642, Standard Test Method for Sealed Tube Chemical Compatibility Test]

IEEE Standards
IEEE 1, Recommended Practice - General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation
IEEE 99, Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment
IEEE 101, Guide for the Statistical Analysis of Thermal Life Test Data

5.6 From the specific material selection to the insulation system and final product approval

Electromagnetic devices operating at elevated temperatures (≥ 120°C) (including motors, transformers, generators and solenoids) often require an explicit electrical insulation system (EIS) test to obtain UL certification.

UL 1446 itself does not require any additional assessment of materials (EIM, NIM) that have direct contact with live parts. This additional assessment is part of the testing of the end device and depends on the design, thermal classification, clearances and other parameters. These are often determined by the relevant terminal device standard.

The process flow from material to system to final product approval is shown below. It should be noted that each step has its own specific standards (e.g. UL 746, UL 1446, UL 1004).

Figure 4: Process flow: From material to final product approval, image source Synflex

Neither the qualification of the individual components nor the electrical insulation system used alone are sufficient to obtain device approval. Each end product standard may require additional parameters, which should be taken into account at the beginning of the new development when selecting materials.
Examples of these parameters are HWI (Hot Wire Ignition), CTI (Comparative tracking index), HAI (High Arc Ignition), etc.. These parameters are also the basis for deciding which materials should be used and tested in an insulation system.

It is helpful that the potentially required additional parameters, which are derived from the end device standards e.g. UL 1004, UL 508 etc. or IEC 61800-5-1, IEC 60034 etc., can already be found in part in the material-specific "Yellow Cards": UL 1004, UL 508 etc. or IEC 61800-5-1, IEC 60034 etc. can already be found to some extent in the material-specific "Yellow Cards".

The UL Yellow Card

The "Yellow Card" lists the product-specific data that has been tested in accordance with the UL 746 series standard, for example, with a focus on safety-relevant properties such as flammability and combustibility (UL94).

Other typical details on the Yellow Card are, in addition to Color, Min. Thickness (mm), Flame Class:

- HAI High-Current Arc Ignition
- RTI ... relative temperature index ...
- RTI $_{\text{Elecder}}$ dielectric strength
- RTI $_{\text{Impder}}$ tensile strength
- RTI $_{\text{Strder}}$ notched impact strength
- HVTR High Voltage Arc Tracking Rate
- CTI Comparative Tracking Index

However, the Yellow Card can also be extended with data, e.g. regarding RoHS or halogen content, which may be required in certain end device standards. In addition, other technical properties tested by UL can also be listed in the so-called "White Cards". In addition to flammability, for example:

- Glow-Wire Flammability (GWFI)
- Glow-Wire Ignition (GWIT)
- IEC Comparative Tracking Index
- IEC Ball Pressure
- ISO Heat Deflection (1.80 MPa)
- ISO Flexural Strength
- ISO Tensile Impact
- ISO Tensile Strength
- ISO Izod Impact
- ISO Charpy Impact

Note: The following databases are available from UL:

1. http://iq.ul.com/systems/: Electrical insulation systems
2. https://iq.ul.com/: UL database overview
3. https://iq.ulprospector.com/en:UL-Produktdatenbank

6 Abbreviations / Glossary

ASTM - American Society for Testing and Materials

CCT - Components Compatibility Test: Compatibility test, also known as "sealed tube test". Used to modify an existing EIS. (better known as "sealed tube test")

CTI - Comparative Tracking Index: Measure of the tracking resistance of a material. The CTI value is standardized up to 600V.

EIS: Electrical Insulating System

EIM: Electrical Insulating Materials: Material or component that is the main electrical insulation (primary insulation)

FTA - Full Thermal Ageing: Test program for the qualification of a complete EIS

GPM - General Purpose Model: Test setup for the FTA

HWI - Hot Wire Ignition: Test to determine the flammability of a plastic using a glow wire

HAI - High-Current Arc Ignition: Test of the resistance of a material and its surface to an arc / ignition **spark**

IEC - International Electrotechnical Commission

NIM - Non-Insulating Material: Material whose primary function is not electrical insulation

OBJY2 --- Designation from the UL Category code numbers system

OBJS2 - Component-Electrical Insulation System Components
(UL recognized systems that are freely available)

RTI - Relative Temperature Index: Temperature index of a material that has been determined relative to another known material as a reference, e.g. by means of an ageing test. This temperature reflects the maximum operating temperature for a defined service life of the product.

RTI - Elec (only if in the Yellowcard example)
RTI - Imp (only if in the Yellowcard example)
RTI - Str (only if in the Yellowcard example)

UL Underwriters Laboratories, Inc. - US organization that defines product standards for electrical products (similar to VDE and TÜV). Products can be certified by recognized testing institutes according to various UL standards.

UL 94 - Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 1446 - Standard for Systems of Insulating Materials - General

VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. The VDE includes the German Commission for Electrical, Electronic & Information Technologies in DIN and VDE (DKE) and the non-profit VDE Testing and Certification Institute GmbH, which awards the VDE test seal.

7 References

- UL Performance materials: Electrical insulation systems and materials (EIS Brochure_A4_en_final) https://industries.ul.com/wp-content/uploads/sites/2/2015/07/UL_EIS-Brochure_A4_en_final.pdf
- UL Brochure; Safety and performance reliability of electrical insulation systems https://library.ul.com/wp-content/uploads/sites/40/2016/07/10193-EIS-White-Paper-R3.pdf
- Standard for Systems of Insulating Materials - General, Standard 1446, Edition 7
- IEC 61858-1 Electrical insulation systems - Thermal evaluation of changes in a tested electrical insulation system (EIS)
- IEC 61857 series, Electrical insulation systems - Thermal evaluation of electrical insulation systems (EIS)
- See also section 5.5: Testing standards and assessment procedures.

8 Image sources

Figures 1-4: SynFlex Elektro GmbH, 32825 Blomberg

9 Summary for cross-readers

Apart from the Full Thermal Aging Test, UL 1446 is an administrative test standard. UL 1446 is primarily used to test the chemical compatibility of the materials used at a given continuous operating temperature. Except for the winding wires, supply cables, surface insulating materials (which are used as EIM material) and insulating varnishes, no thermal class classification is tested. It is therefore sometimes possible to submit materials that have no UL classification or a UL approval with a lower thermal class. Exceptions to this are materials that may be prescribed due to the intended end use.

The IEC 60085 standard is the international equivalent of UL 1446, but it is not identical! A corresponding IEC guideline can be found in IEC 60505.

Laboratories that are qualified by UL under the UL Third Party Test Data Program for the insulation system tests listed here carry out corresponding projects in accordance with UL Standard 1446, such as the FTA or CCT test. It is also possible to authorize the laboratories as agents, which then carry out the overall processing of corresponding UL projects.

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