ZVEI: Die Elektroindustrie

Guide to

Certification of Electrical Insulation Systems according to UL Standard 1446 Ed.7

Electrical Winding & Insulation Systems Division

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Guide to Certification of Electrical
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Content

1 Introduction

In the course of globalization and global trade, certification of the products of the German electrical industry is playing an increasingly important role. Only safe products, i.e. products that have been tested and certified by recognized testing and certification institutes find today customers on the world market.

Underwriters Laboratories

One of the most widely used certification marks is the American *UL Mark*. It is often required for products to be sold in the North American market. The mark is managed by Underwriters Laboratories LLC. (UL), founded in 1894, based in Northbrook, Illinois. The UL perform similar tasks as VDE or TÜV.

UL is a leading organization in the US in the field of electrical safety. Various product standards cover the entire spectrum of electrical and electronic products and applications. If one compares the safety philosophies between the VDE and the UL, one quickly identifies serious differences: While the VDE focuses on the individual components of the tests, the overall system is the focus of the tests at UL.

The Edition 7 of the standard UL 1446, puplished 11/11/2016, brings some innovations and more clarity into the certification process of electrical insulation systems (EIS) at UL. The previous version, 1 trough 6, remained the same as the scope of the standard for EIS, in which thermal stress is the decisive factor for aging. (UL1446 Editions 1 through 6 was focused on consumer goods, meaning applications operating in the voltage range below 1kV, and the American marketplace.)

What is new, however, is that with regard to testing, preference is given to IEC (International Electrotechnical Commission) standards. The usual North American ASTM (American Society for Testing and Materials) standards are considered technically equivalent. The second major change is that UL1446 Ed.7 became a standard focused on the thermal evaluation and classification of EIS regardless of operating voltage. UL 1446 Ed.7 is linked to IEC 61857-2 Electrical insulation systems – Procedures for thermal evaluation – Part 2: Selection of the appropriate test method for evaluation and classification of electrical insulation systems.

These significant improvements bring a new structure to this standard. The clearer structure makes it easier to understand how the requirements for insulating materials are to be understood depending on the intended use. An entry in the corresponding section of the standard is thus easier.

The UL 1446 Ed.7 thus provides the industry with a user-friendly, harmonized and practicable standard. It is important that existing systems continue to be valid. Changes resulting from the new edition have to be applied only in the context of new projects.

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2 How is the UL 1446 to be understood?

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

An important component is, among other things, Table 4.1, which classifies system components into electrical insulation materials (EIM) and materials not used as electrical insulation (NIM) and thus sets the requirements for the test requirements of the individual materials derived from them.

An informative appendix on the substitution of enameled wire naming the IEC types completes the standard.

The standard UL 1446 is therefore a general guide to the creation and expansion of electrical insulation systems.

3 Reliability of electrical equipment

The state of electrical equipment is crucial for safe operation. High reliability, good efficiency, low failure probability, low maintenance costs decide today on the use of the equipment. A very important characteristic here is the aging behavior, which is caused by the load on the system.

Here one can distinguish between

- electric
  (leakage currents, partial discharges or interface processes),
- chemical
  (chemical incompatibility, e.g., plasticizer degassing, degradation),
- thermal
  (diffusion or thermo-mechanical alternating load, substance degradation),
- mechanical
  (vibration and shock loads, infiltration, abrasion) and
- environmental
  (UV radiation, weathering, salt spray)

aging.

The electrical aging is based on physical processes, such as leakage currents, partial discharges or interfacial processes. The aging function, i.e. the dependence of the service life on the load, follows an (empirically determined) inverse life-time law

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

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

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

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

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

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

The mechanisms of aging can be intrinsic or extrinsic. A temporary deterioration of the state of the equipment is referred to as degradation, a permanent deterioration is a permanent change to the electrical insulation system.

The listed aging mechanisms lead to a weakening of the insulation materials, which determine the electrical reliability. In the worst case, it 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 called an EIS (Electrical Insulation System) and is often very individual in design and application. The reliability of the EIS depends on the compatibility of the EIM materials to each other and thus their response as a system. The UL 1446 covers the guidelines and test methods for evaluating the thermal performance of insulating materials and their interaction as a whole under heat load.

4 Composition and components of an electrical insulation system

For winding products reliability in operation and longevity are closely linked with the insulation technology used. Operating temperatures may lead to chemical reactions involving aging, associated with weakening of the material, resulting in hazardous operating conditions (such as fire, risk of contact with live parts).

Winding products themselves consist of a large number of components. For the function itself, the coil(s) of winding wire (copper wires, braided wires, etc.) and the permeable core (electrical steel, ferrite core, etc.) may be mentioned. The winding material is built up in most cases on a winding body, or coil form, with insulating intermediate layers.

The winding itself must be constructed so as to provide protection against contact with live parts and protection against ignition at operating temperature. Components such as surface insulating materials, the impregnating lacquers / resins, the supply lines, the insulating hoses, but also the potting compound that may be used are used to ensure the handling and operation.

The reliable interaction of all components made of electrical insulating materials (EIM) in an electrical insulation system (EIS) is given in 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) differentiates in principle between system components that are used as electrically insulating materials (EIM) and as materials not used for electrical insulation (NIM)[1].

[1] Note: the previous designations Major and Minor Components are no longer used. See Section 5 Table 1 for details.

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 e.g. a specific motor or transformer. The second category "Component - Electrical Insulation System Components (OBJS2)" is intended for use in a third-party application[2]. It is managed in the iQ Electrical Insulation System Database and made available to customers by major manufacturers. An approval for the Canadian market can be applied for in the project.

Each EIS to be certified, in turn, consists of a large number of individual electrical insulating materials (EIM), which are divided into components with insulating function and components whose function is not primarily an insulating function. The differentiation is based on the assumption that components with insulating function are of particular importance for the protective effect with regard to electrical safety and fire behavior, that is to say represent the insulating barrier between the various electrical potentials. On the other hand, 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 insulating function are referred to in German usage as primary insulation.

Function	Describtion	Component
electrical insulating function **EIM**	Components whose failure results in serious security losses	Enamelled copper wire bobbins performance insulating material impregnants[3]
other function **NIM**	Components whose failure does not result in significant loss of security (typically used for thermal or mechanical connection)	Feedline wires Insulating hoses Insul. Layer materials Winding tapes encapsulants

Table 1: Examples of important components

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

[2] The expected pattern of UL is that OBJY2 files are restricted and not to be published other than acknowledgment the EIS exist. However, the OBJS2 category is expected to be in the UL iQ database for potential users to find the information.

[3] Impregnants are considered insulating components if they were tested in the original Full Thermal Aging test and affected the overall performance of the system.
Otherwise, they are classified as non-insulating component and must be inserted via an impact assessment (see 5.2).

5.1 Full thermal aging test (FTA)

In order to be recognized as a UL Recognized[4] 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 testing CCT (Component Compatibility Testing), also known as sealed tube testing, may be sufficient.

The UL recognition according to UL 1446 EIS requires a test setup described in IEC 61857-21. This test setup, the so-called general purpose model (GPM), is colloquially also called the Motorette (simplified model of an engine). To assess the temperature class up to which an EIS may be used, the GPM models are aged at at least three different temperatures.

System classes	Max. Spitzentemperatur [°C]
120 (E)	120
130 (B)	130
155 (F)	155
180 (H)	180
200 (N)	200
220 (R)	220
240 (S)	240
Über 240 (C)	über 240

Table 2: System classes acc. UL 1446. For further details see also IEC 61857-1 table 2

Secondary constituents / (Minor Components) (NIM materials) may or may not be part of the test, but may be added later by truncated tests, e.g. be verified by CCT test.

[4] UL uses the word certification to refer to the process; the process of the evaluation in accordance with the appropriate standard. UL uses two additional terms to distinguish between a finish ready-to-use product and a component or item expected to be used in the manufacturing of a finished ready-to-use product; Listed and Recognized.

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

Recognition – This word is used for all components of any type which are expected to be used not on its own but as a component of some type in a finished ready-to-use product. This includes actual components and technical information such as the report of the evaluation and classification of a material or an EIS.

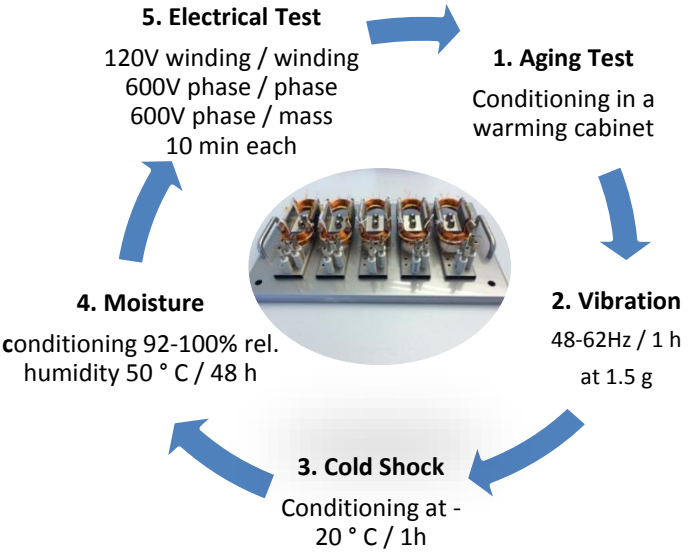

Illustration 1: Test procedure FTA, Photo Credits Synflex

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

The test must be performed at at least three different temperatures to give a reliable estimate of the appropriate temperature class.

The following table shows the aging cycles in the test procedure:

Test cycle UL 1446	**execution**	
Temperature test (aging)	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

Test cycle IEC 61857-1	**execution**	
Temperature test (aging)	Highest temperature: Next lower 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 multipurpose models (GPM) per temperature are required. The temperatures to be applied depend on the desired thermal class and the possibilities of loading the materials beyond the desired thermal class. A 180 (H) system may e.g. be tested at 200°C, 220°C and 240°C, but can also be tested at higher or lower temperature.

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

1.) Complete Aging Test (FTA)

2.) Supplementation of the secondary components and also main components (taking into account the specifications according to UL1446) by Sealed Tube Test (CCT))

3.) Use of the EIS in the final application

As a rule, about one year passes before the approval of a completely new EIS.

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

As an alternative to a time-consuming full aging test, many users can use the compatibility test to add the required components without an insulating (NIM) EIS. This is described in IEC 61858 Annex B. Clearly, it must be emphasized that it is only possible to a limited extent to supplement or replace components with insulating function (EIM) in an existing EIS. Permitted changes to an insulation system are described in IEC 61858. On the other hand, copper enameled wires can be added / replaced according to the conditions in UL 1446 or IEC 61858 Annex A.

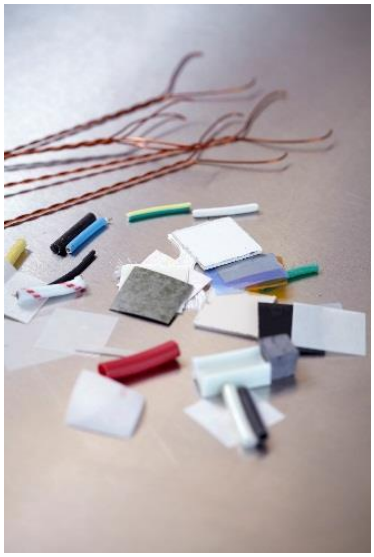

Illustration 2+3: Sealed Tube and hot cabinet (Photo Credits Synflex)

The compatibility test is a standardized procedure that tests the chemical compatibility of the main insulation materials with respect to the interactions with the accompanying

minor components (for example, insulating hoses, insulating materials, adhesive tapes, pigtails, potting compounds, cords, etc.).

The main focus is on the electrical resistance of the enamel-insulated wires. This is determined after 14 days of common storage of all components of the EIS in an airtight glass envelope (sealed tube). Aging takes place at the desired heat class temperature, plus 25°C. As a reference, another airtight glass bulb (sealed tube) is filled only with the components of the original ICE and aged in the same way.

The modified EIS is approved if the withstand voltage of the winding wires reaches at least 50% of the winding wires of the reference tube after appropriate aging. After performing the sealed tube test, 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 modified to meet your own needs, it is necessary to contact the "owner" of the OBJS2 system. He has to 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 exposes all components in the original EIS. With this information, the submitter can then compile the sample materials for the CCT.

Based on the experience of UL, electrical insulating tapes can be categorized into so-called matrices. The idea is that many adhesive tapes of a manufacturer differ only in their strength, color or transparency. However, the chemical structure is identical, so that no other influence on the winding wires in the sealed tube test is to be expected. In agreement with UL, it is possible in this way to reduce the number of adhesive tapes to be submitted.

A CCT is one way to extend the list of acceptable materials to an FTA or an existing EIS system without waiting for a full FTA. This review takes about 4-8 weeks subject to availability of material.

It is the responsibility of the submitter to provide all necessary components for the Sealed Tube Test. The final approval is documented in a so-called UL file. UL has developed a database containing the results of tested and approved EIS (www.ul.com/iq).

5.3 Takeover of an existing EIS

The fastest, most cost-effective way to define your own EIS is to adopt an existing EIS without any modification.

Since it is not necessary to use all the components of such an EIS, the user is therefore looking for an EIS that contains all the required components.

The acquisition of an existing EIS takes place in two possible ways:

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

A separate permission by the current owner of the original EIS is required in the form of an "Authorization Letter".

Modifications are possible when adopting 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 done exclusively by UL. With sufficiently high similarity, the products can be supplemented after approval by UL without further testing.

5.4 Other specific UL approval procedures for insulating materials

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

5.4.1 Defined Life Thermal Aging (DLTA)

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

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

It requires fewer samples and less testing time than conventional full thermal aging. The test requirements are contained in IEC 61857 Part 31 "Applications with a lifetime of 5 000 h or less".

After completion of a DLTA program, a CCT project can be opened to optimize the system.

With the help of the CCT test, NIM materials can, under certain conditions, be added to an existing EIS. The CCT test examines the chemical interaction at elevated temperatures of all components of the extended EIS. The assessment criterion is the dielectric strength of the twisted enameled wire (twisted pairs) in the sample. See 5.2

5.4.2 Short Term Thermal Aging (STTA)

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

The STTA program is a new service which evaluates an electrical insulation system for motors in low voltage applications (⩽ 1000 volts).

The Short-Term Thermal Aging (STTA) test for engines has been specifically designed to enable customers to accelerate the market launch according to the UL 1004 series "Rotating Electrical Machines". The test requirements are contained in ANSI / UL / IEC 60335-1 Annex C and include aging of six production engines at elevated temperatures and humidity. Compliance with the requirements is determined by an electrical test (fault current and electrical resistance).

Below is the test time, which is determined from the desired temperature class and corresponding increase in temperature.

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

- Reduced time to market due to short evaluation period (about 3 months)
- Low sample buildup saves costs and time compared to the current engine test program.

Approval / classification

The results of the STTA assessment are engine design and type specific, and provide limited flexibility in material procurement and end-use options compared to the traditional FTA program. Engines undergoing this program are reviewed every three years to ensure that deviations in engine production processes have not affected the performance of the EIS.

A positive STTA test results in the UL category OBJY3 for use in motor constructions acc. Standard UL 1004 Series (Electric Rotary Machines). Systems compliant with the requirement IEC 60335-1 Appendix C, receive a System Certification Report describing which insulating materials were used for the evaluation. The insulation system can be used for other motors of the same series, taking into account identical insulating materials.

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

A CCT project may also be performed after an STTA, but is limited to NIM (non-electrical insulating materials), such as e.g. tapes, hoses, cable ties, leads and cords. See 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 is carried out in the UL conducted (follow up) inspections on site (at the production site).

5.5 Test standards and evaluation procedures

There are several ways to generate or modify an electrical insulation system. The test standards used for this purpose are described in the following table. As a preferred test method, the IEC is used. If there are no IEC standards, the ASTM / 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

Table 6: Test standards for the evaluation of electrical insulation systems (without claim to completeness)

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

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

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

The process flow from the material through the system to end 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).

Illustration 4: Process flow: From material to end product approval, image source Synflex

Neither the qualification of the individual components nor the electrical insulation system used alone is sufficient to obtain a device approval. Each end product standard may require additional parameters that should be considered at the beginning of the new development in material selection.

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 to use and test in an isolation system.

It is helpful here that the potentially required additional parameters, which are derived from the terminal standards such as: UL 1004, UL 508 etc. or IEC 61800-5-1, IEC 60034, etc., already partly in the material-specific yellow cards are found.

The "Yellow Card" lists the product specific data, e.g. tested according to the standard UL 746 series, with a focus on safety-related properties such as flammability, flammability (UL94), the above-mentioned HWI, CTI and HAI as well as the RTI (Relative Temperature Index).

The yellow card can also be extended with data, e.g. regarding RoHS or halogen content, which may be required in certain terminal standards. In addition, other technical properties tested by UL can also be listed in the so-called "White Cards".

Further typical contents are, besides Color, Min. Thickness (mm), Flame Class:

HAI	High-Current Arc Ignition
RTI …	relativer Temperatur-Index bzgl. …
RTI Elec	der Durchschlagfestigkeit
RTI Imp	der Zugfestigkeit
RTI Str	der Kerbschlagzähigkeit
HVTR	High Voltage Arc Tracking Rate
CTI	Comparative Tracking Index

The Yellow Card can also be extended with data, e.g. regarding RoHS or halogen content, which may be required in certain terminal 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)	ISO Tensile Strength
Glow-Wire Ignition (GWIT)	lSO Flexural Strength
IEC Comparative Tracking Index	ISO Tensile Impact
IEC Ball Pressure	ISO lzod Impact
ISO Heat Deflection (1.80 MPa)	ISO Charpy Impact

The technical data mentioned are summarized by UL in the Yellow Card as shown schematically below:

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- product database

6 Abbreviations / Glossary

ASTM – American Society for Testing and Materials

CCT --: Components Compatibility Test: Compatibility testing, 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 mainly represents the electrical insulation (primary insulation)

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

GPM – General Purpose Model: Test set-up for FTA

HWI – Hot Wire Ignition: Test for determining the flammability of a plastic by a filament

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

IEC – International Electrotechnical Commission

NIM – Non-Insulating Material: Material whose function is not primarily the electrical insulation

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

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

RTI – Relative Temperature Index: Temperature index of a material that has been referenced relative to another known material, e.g. through an aging test. This temperature reflects the maximum operating temperature for a defined life of the product.

RTI – Elec (only if within the Yellowcard Example)
RTI – Imp (only if within the Yellowcard Example)
RTI – Str (only if within the Yellowcard Example)

UL Underwriters Laboratories, Inc. - US American organization that defines product standards for electrical products (similar to VDE and TÜV). Products can be certified by recognized testing institutes for 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 German Commission for Electrical Engineering Electronics Information Technology in DIN and VDE (DKE) and the non-profit VDE Testing and Certification Institute GmbH which awards the VDE seal of approval.

7 References

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- 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 61 858-1 Elektrische Isoliersysteme - Thermische Bewertung von Veränderungen an einem erprobten elektrischen Isoliersystem (EIS)
- IEC 61 857 Serie, Elektrische Isoliersysteme - Thermische Bewertung von elektrischen Isoliersystemen (EIS)
- See also Section 5.5: 5.5 Test standards and evaluation procedures

8 Image sources

Images 1-4: SynFlex Elektro GmbH, 32825 Blomberg

5: UL-Underwriter Laboratories, Northbrook (Illinois)

9 Summary for cross readers

The UL 1446 is an administrative test except for the Full Thermal Aging Test. Above all, the UL1446 tests the chemical compatibility of the materials used at a given continuous operating temperature. No heat class classification is checked except for the winding wires, feed lines, surface insulation materials (which are used as EIM material) and insulating varnishes. It is therefore partly possible to submit materials that do not have any UL classification or UL approval with a lower thermal class. Exceptions to this are those materials that may be required due to the intended end use.

The standard IEC 60085 is the international equivalent to the UL 1446. However, it is not identical! A corresponding IEC guide can be found in IEC 60505.

Laboratories qualified by UL under the UL Third Party Test Data Program for the UL listed insulation system tests, can perform corresponding projects acc. the UL standard 1446 such as the FTA or CCT test. There is also the option of authorizing the laboratories as agents, who then carry out the overall processing of corresponding UL projects.

Space for your notes:

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