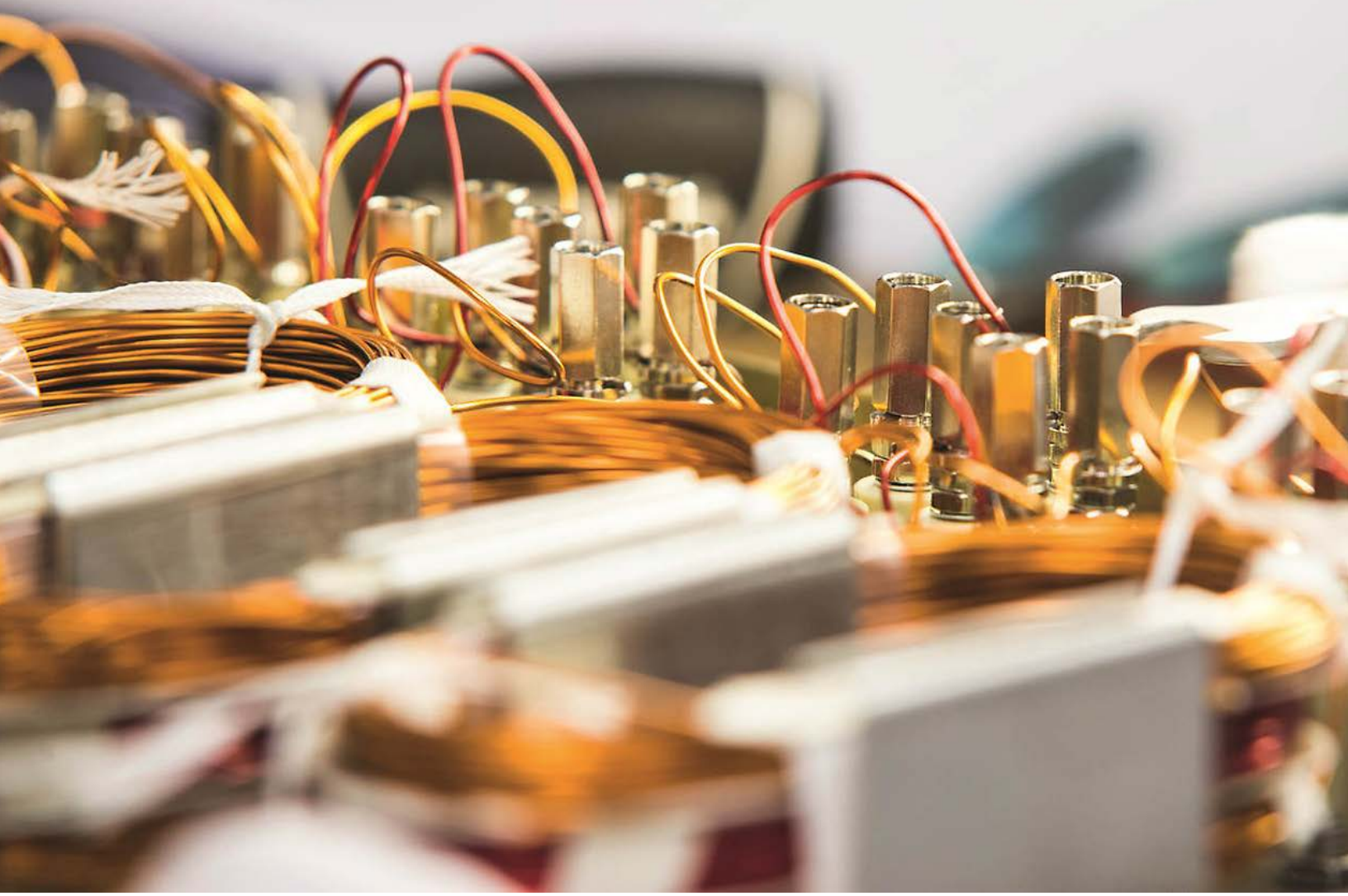
WHITE PAPER

Electrical Insulation Systems Certification Supply Chain Preparedness



UL Solutions

Safety. Science. Transformation.™

Safety and performance reliability

Safety and performance reliability are essential attributes for an electrotechnical device, such as a motor, transformer, generator, solenoid, etc., and the electrical insulation system (EIS) used in the device is a critical link. An EIS is a unique combination of electrical insulating materials (EIM) used in electrical equipment, closely packed together, operating at or below the maximum operating temperature of the device. An example is the combination of magnet wire, slot liner insulation, end cap insulation and impregnating resin in a motor.

The main function of EIM is to provide a dielectric barrier between one voltage potential and another voltage potential, and between grounded or dead metal. All other materials used for mechanical support or construction purposes and not relied upon to provide electrical protection are considered nonelectrical insulating materials (NIM).

Since the EIM used to build an EIS are plastics, the production of a device requiring a certified EIS may be severely disrupted whenever there is an event, foreseen or unforeseen, that impacts the availability of plastics. This was recently demonstrated when polymer producers declared a force majeure to their customers because of a shortage of raw materials.[1]

This UL Solutions white paper will describe how EIS certification may be retained when disruption occurs, as well as ways to plan for any future disruptions. It's a follow-up to a UL Solutions white paper published in 2022, "Reliability of Electrical Insulation Systems," which provides in-depth details about EIS, including their history, testing and certification process. For those readers who do not yet have a basic understanding of EIS and EIM, we recommend you read that paper first.

© 2023 UL LLC. All rights reserved.

Immediate supply chain disruption strategies

UL 1446, the Standard for Systems of Insulating Materials – General, includes requirements for determining the safety and reliability of an EIS used in electrical equipment and components subjected to operating temperatures greater than 105°C. As a result of testing to this standard, EIS are certified to one of the two following categories:

1

Systems, Electrical Insulation (OBJY2)

This category applies to complete EIS built or assembled by a magnetic device manufacturer from a unique combination of components.

2

System Components, Electrical Insulation (OBJS2)

This category applies to complete EIS that are established by an EIM manufacturer — typically, moldable resins, sheet films and impregnating varnishes manufacturers.

When an electrotechnical device manufacturer experiences a materials shortage and the certified OBJY2 EIS they employ in their product cannot be built according to the existing bill of materials, it is necessary to find an alternate source. A certified OBJY2 EIS is a unique combination of materials, and any changes to a material need to be evaluated for compatibility with the other existing materials to maintain compliance with certification requirements covered in the UL 1446 Standard.

When a change needs to be made to the OBJY2 EIS due to material shortages, the fastest way to maintain compliance is to adopt a certified OBJS2 EIS. These can be found in the UL iQ™ family of databases — specifically, UL iQ™ for Electrical Insulation Systems. These EIS have gone through the required testing for certification and can be adopted into an OBJY2 file without additional testing.

Use this database to search for an OBJS2 EIS that may meet your material construction needs. You should start your search for the most critical components: temperature class, magnet wire type and electrical insulating materials, e.g., ground and interwinding insulation, bobbin, slot liner, end cap. If an OBJS2 EIS is found that has the necessary EIM, additional short-term testing may be conducted to add NIM such as tapes, tubing and lead wire.

Substitution of an identical NIM component from an alternate supplier may be investigated by qualitative infrared analysis to determine whether substitute materials are at least chemically equivalent to the original materials. The short-term test used most frequently to add NIM to an EIS where the NIM is not identical is the sealed tube chemical compatibility test (CCT). This test evaluates the compatibility of additional materials with the winding wire insulation.

For motor manufacturers, there is the short-term thermal aging (STTA) test for motors. The test requirements are covered under Annex A of UL 1004-1, the Standard for Rotating Electrical Machines – General Requirements, and involve cycling the actual motor insulation through elevated temperatures and humidity exposures for four cycles totaling 1,000 hours. Compliance is determined via an electric strength test on the motor insulation.

© 2023 UL LLC. All rights reserved.

EIS full thermal aging

It's important to note that the approaches mentioned above may not be possible if there is no available OBJS2 EIS that will meet construction needs, or for devices other than motors where an STTA test is not possible. An alternate service for establishing a certified OBJY2 EIS is a full thermal aging (FTA) of the EIS, which is covered in Section 7 of UL 1446. Testing is typically conducted using general purpose models (GPM), which allows for the evaluation of multiple types of EIM.

All EIM in a UL certified EIS were originally evaluated by the FTA test to establish the temperature classification of the EIS.

All EIM in a UL certified EIS were originally evaluated by the FTA test to establish the temperature classification of the EIS. The FTA is a long-term thermal aging test that may take more than one year to complete. Therefore, it is not considered an immediate option for a supply chain disruption. It is an opportunity for those who prepare before disruption occurs to best position themselves for navigating a supply chain disruption.

The development stage of an electrotechnical device is an excellent time to make decisions on the EIM that should be considered for use in the design and subsequent evaluation for certification. Design decisions may be driven by material usability in manufacturing, material performance and the price of materials as sourced through a purchasing department.

For materials where production costs and manufacturing play into the design parameters, it may be valuable to consider alternatives at this stage. This is particularly important knowing that those materials may:

- Increase in price
- Become obsolete and no longer be produced
- Be unavailable due to supply chain disruptions

Then, when EIS testing for certification is performed, these alternate materials can be included in the evaluation and, upon successful completion of the testing, will be available for use without the need for additional evaluation if and when a change is necessary.

© 2023 UL LLC. All rights reserved.

Creating a robust supply chain for EIS

When developing a robust supply chain for a certified EIS, it is important to consider the materials intended to be used to build the electrotechnical device, as well as what alternatives should be included in the certification evaluation for when intended materials are not available.

Here are some things to consider when deciding what materials to have evaluated:

The flexibility of the manufacturing process to change from one material to another

Will changing a material require retooling, extensive programming or changes in assembly order and workflow?

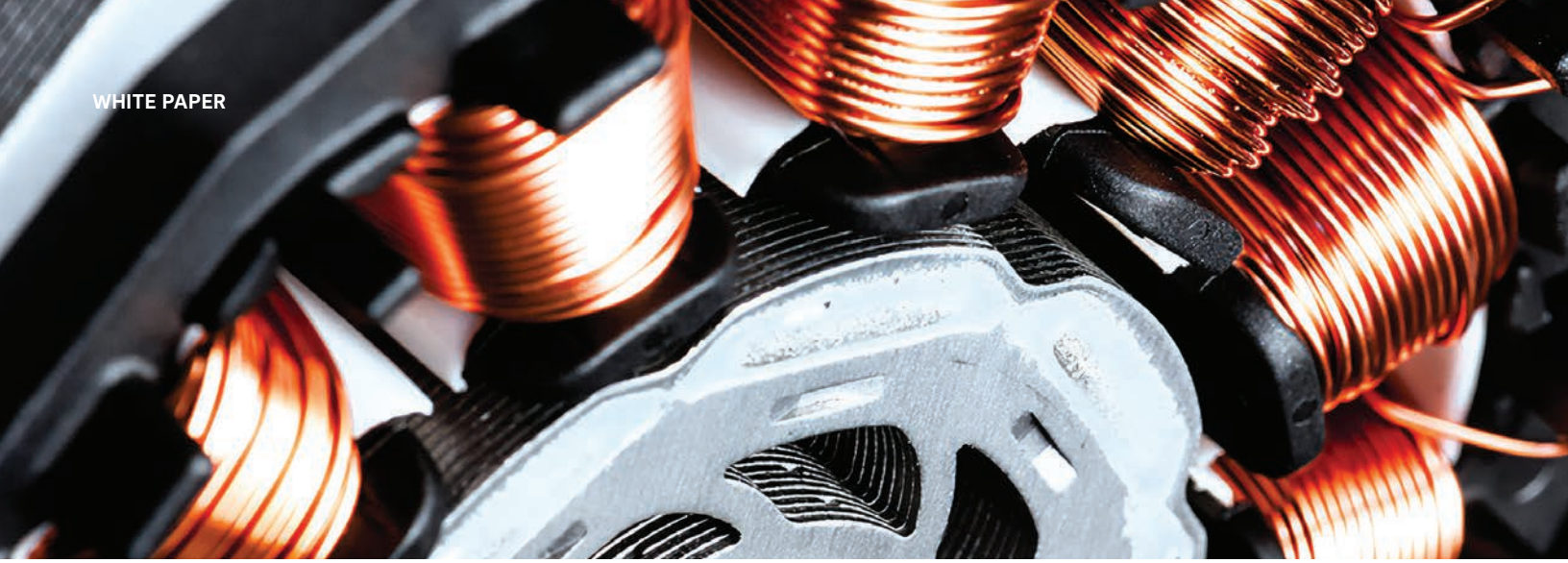
Challenges with the moldability of various plastic grades to produce suitable parts

Plastics with the same chemistry may mold similarly to produce suitable parts. To provide for an alternative that is not of the same chemistry, will the alternative be compliant with molding equipment and/or will the molded product be able to perform with the same expectations as the original?

The use of flexible sheet insulations and their suitability for the manufacturing process

Is switching from one chemistry or construction to another possible — for example, aramid paper versus polyethylene terephthalate (PET) film versus polyimide film? Will a switch require the use of a laminate, like aramid paper/PET film/aramid paper, commonly known as NMN? Note: A base film like PET may be evaluated in the FTA test, and then laminates that are constructed with the PET film layer may be added by short-term CCT to evaluate chemical compatibility of adhesive and other layers.

© 2023 UL LLC. All rights reserved.



The use of varnish impregnation and the ability to change from one type to another

What are the challenges in production to switch from one varnish type to another, i.e., polyester to epoxy? Note: FTA testing without varnish allows for easier substitution of OBOR2 varnish with a suitable twisted pair rating by short-term CCT.

The approved vendor list may require time to update

When using different suppliers/grades, consideration should be given to the process for qualifying vendors and internal updating procedures.

The purchasing department may want to add new material(s) and supplier(s) to the list

Purchasing may negotiate a favorable contract for a product and want manufacturing to use it in the product. However, it will need to be evaluated in the EIS to determine its compliance with UL 1446. Consider other vendors' products that will work as alternatives based on engineering recommendations and have them added to the approved vendor list and included in certification testing.

The above considerations were developed from years of experience in evaluating EIS and from the situations that prompt change. There may be additional considerations unique to individual manufacturers that might need to be addressed.

When considering materials for evaluation in an FTA test with GPM samples, it is possible to evaluate up to six different flexible sheet materials, 12 different moldable polymers and three different types of magnet wire. This level of variability gives manufacturers greater flexibility in using alternate materials and suppliers.

When a specific material is not available — for example, due to a force majeure or elevated material cost that makes a product less profitable — alternate materials exist within the EIS that can be used in production without needing to conduct further EIS testing.

© 2023 UL LLC. All rights reserved.

Summary

In the short term, when a supply chain disruption occurs, it is possible to make changes to an EIS that will help keep production online. The evaluation of changes will require time to conduct and helps for the specific supply chain issue. However, the evaluation cost may not be anticipated and might have a negative impact on expenses.

An EIS established by FTA helps the manufacturer:

- Be ready before the threat of material availability impacts their production
- Control the selection of alternate material components
- Address unique production scenarios
- Budget for evaluation costs as an expected expense

Understanding the importance of creating an EIS built around material diversity early in the product development phase typically results in better methods for smoothly navigating supply chain disruptions, containing costs and reducing delays.

UL Solutions is a pioneer in developing and applying standards applicable to EIS, and offers a wide range of testing and certification services for various types of insulation systems and components.

For further information about UL Solutions electrical insulation system services, visit www.UL.com/EIS.

Creating an EIS built around material diversity early in the product development phase typically results in better methods for smoothly navigating supply chain disruptions.

Endnote

[1] Vakil, Bindiya, "The Latest Supply Chain Disruption: Plastics," *Harvard Business Review*, published March 26, 2021, accessed August 2023, (hbr.org)

© 2023 UL LLC. All rights reserved.

UL.com/Solutions

© 2023 UL LLC. All rights reserved. This document may not be copied or distributed without permission. It is provided for general information purposes only and is not intended to convey legal or other professional advice.

EM23CS1120001