UL 1446 – Systems of Insulating Materials

The Process for Adding Minor Insulation Materials to Dry Type Transformer Insulation Systems

The purpose of this document is to present the process used by The Gund Company to assist our customers in adding minor insulation materials to their dry type transformer insulation systems to increase their sourcing flexibility, shorten their material lead-times, lower their material inventories, and reduce their material costs.

By outlining a streamlined process for adopting The Gund Company's insulation system test results, our customers can incorporate the use of a wider range of minor insulation materials. Without question, the entire process for insulation system testing is confusing, complicated, and convoluted. Our effort to simplify the process is based on the expert advice of Ed VanVooren of Eltek Laboratories, the materials testing lab that performs more insulation system testing than the sum total of the rest of the labs in the world combined. By following this process, minor insulation materials can be added to a dry type transformer insulation system within four to six weeks.

Custom Fabrication

The ANSI / UL 1446 standard for systems of insulating materials specifies the test procedure requirements for the evaluation of Class 120 °C or higher electrical insulation systems intended for connection of branch circuits rated at 600 volts and less. Specific to the purpose of this document, the requirements cover the investigation of the substitution of minor components of insulation in a previously evaluated insulation system. Though outside the scope of this document, the standard also establishes the test procedures to be used in the evaluation of major system components including magnet wire coatings, magnet wires, and varnishes.

Per ANSI / UL 1446 an insulation system is a unique combination of two or more insulating materials used in electrical equipment. One example is the combination of magnet wire, ground insulation, varnish, lead wire insulation, and outer wrapping of a coil. The IEC document 61857 essentially covers the same scope defining an electrical insulation system (EIS) as an insulating structure containing one or more electrical insulating materials together with associated conducting parts employed in an electrotechnical device.

An insulation system temperature class is numerically equal to a maximum hot-spot operating temperature. Hot-spot temperatures for various insulation systems are specified in Table 1. The methods for measuring temperatures and determining hot-spot temperature allowances are specified in end-use equipment standards typically published by UL, NEMA, ANSI, and/or IEC.

Table 1- Hot-spot Temperatures for Various Insulation Systems:

Bobbin or Core Tube	Maximum Hot-Spot Temperature	
	°C	°F
120 (E)	120	248
130 (B)	130	266
155 (F)	155	311
180 (H)	180	356
200 (N)	200	392
220 (R.)	220	428
240 (S)	240	464
over 240 (C)	over 240	over 464

According to ANSI / UL 1446 definitions, insulation systems have two components:

Major Components — The components of an insulation system that are relied upon to prevent a risk of electric shock or fire. Examples of this type of insulation include ground, interwinding, turn, encapsulant, and varnish.

In a tyical dry type transformer design, the major components would be:

Bobbin or Core Tube	It is major when it is the sole insulation between the windings and grounded or dead metal. (i.e. when the tube is the only insulation between bare conductor windings and grounded metal)
Enameled Magnet Wire	Winding wire that relies on its enamel coating for turn insulation.
Encapsulant	A molding that is typically cast or injection molded around the electrical insulation system and is intended to insulate and protect the winding wires.
Ground Insulation	The electrical insulation between the conductor and grounded or dead metal.
Integral Ground	A coating, such as an epoxy, that is fused directly to the grounded or dead metal core and serves as ground insulation.
Interwinding Insulation	The electrical insulation between the individual windings.
Non-enameled Covered Conductors	Winding wire that relies on paper or film layers for turn insulation.
Turn Insulation	Any material relied upon to isolate adjacent turns of the same conductors.
Varnish / Impregnating Resin	A liquid insulator that coats or impregnates the coil and is cured. Varnish properly refers to a solvent-based liquid; impregnating resin refers to a solventless liquid.

Note that the only major components supplied by The Gund Company in a typical dry type transformer design would be the paper turn or ground insulation used to insulate a conductor from grounded metal or an adjacent conductor (i.e. Nomex®)

Minor Components — The components of an insulation system that are used typically in mechanical or thermal conduction capacities, and are not relied upon to prevent risk of fire or electric shock

In a typical dry type transformer design, the minor components would be:

Bobbin or Core Tube	It is minor insulation when another insulating material is placed between the winding and the core in addition to the core tube / bobbin.
Cross Over Insulation	Component providing isolation between the magnet wire at the point where it enters the coil and all subsequent layers in the same winding.
Layer Insulation	The material interleaved between successive layers of an insulated conductor in the same winding.
Outer Wrap	The material that is placed over the final layer of the winding assuming there is a 1/32" minimum air gap separating it from grounded or dead metal.
Securement Tape	Tapes used in mechanical applications only, and have not been evaluated as electrical insulation within the system.
Sleeving and Tubing	Materials that are typically used to cover electrical connections.
Spacers, Winding Combs and Wedges	Materials that are used in a mechanical capacity within the device.

Note that most dry type transformer designs use The Gund Company's materials (insulating paper, composite laminate parts, sleeving, tape) as minor insulation components

According to UL 1446 requirements, an insulation system will be investigated to determine whether the components within an insulation system are compatible and to establish a temperature class for the system. It is important to note that insulating materials having different assigned temperature classes can be combined to form an insulation system having a temperature class that is higher or lower than that of any of the individual components. The compatibility of an insulating material (of any thermal index) with other materials in an insulation system can be investigated to determine whether thermal aging of such materials makes the system susceptible to unacceptable deterioration that inhibits intended performance in normal service at the assigned temperature class of the system.

In other words, a material with a thermal index of 155 °C could be used in an insulation system with a thermal class of 220 °C if the materials are confirmed to be chemically compatible.

The UL 1446 standard establishes the process (Section 11) for creating a new insulation system with an assigned thermal class based on the testing process results. Interpreting the standard and applying it to a specific process for creating a new insulation system can be a bit challenging. Eltek International University (*www.elteklabs.com*) provides a complete course explaining the process with specific steps that a manufacturer can easily follow to create a new insulation system. However, this process is beyond the scope of this document.

The UL 1446 standard also establishes the process (Section 14 and Section 15) for adding a new minor insulation material or component to an existing insulation system. The purpose of this document is to make the process for adding a new minor insulation material to a dry type transformer insulation system easier to understand and easier to implement with the assistance of The Gund Company.

According to UL 1446, there are two methods for adding a new minor insulation to an existing insulation system:

1) Infrared Analysis Testing — Infrared qualitative analysis tests (UL 1446, Section 15) can be conducted in accordance with *UL Standard 746A, standard for polymeric materials – Short Term Property Evaluations.* UL Standard 1446 has almost no explanation of this process or its application. Infrared analysis involves qualitative (meaning opinionated) comparison of the chemical composition of a candidate material versus a previously qualified reference material.

   In short, if the chemical signature of one material is deemed to be "equivalent" to a material already in an insulation system, then the candidate material may be added to the insulation system. The theory is that two materials with identical chemistry will have the same chemical compatibility properties in an insulation system.

   Per UL 1446 Section 8.2 titled Minor Components:

   "8.2.1 Substitution of an identical minor insulation component from an alternate supplier shall be investigated by subjecting samples to one or more short-term tests, such as qualitative infrared analysis, thermogravimetric analysis, dielectric strength, or other appropriate tests, to determine whether substitute materials are at least equivalent to the original materials."

   Related to this point, UL's Material Certification Program (known commonly as the UL Yellow Card) includes a reference to a rigid material's ANSI Grade. If two materials have the same ANSI Grade designation on their respective UL Material Certifications, then those two materials have "equivalent" chemical signatures and can be substituted for each other in an approved insulation system.

   For example, the UL Material Certification for Glastic® Grade UTS has the ANSI designation GPO-2 as APO-2 from The Gund Company. So, the APO-2 Grade from The Gund Company can be substituted for Glastic® UTS because they are chemically equivalent according to UL procedures.

Industrial Laminates:

Material Dsg.	ANSI type	Color	Min Thk. mm	Flame Class	RTI Elec.	RTI Mech.	HWI	HAI	HVTR	CTI	Meets 746E DSR
UTS 1478, UTS 1479, UTS 1431, UTS 1471, UTS 1472, UTS 1474, UTS 1410											
GPO-2	GPO-2	RD	0.74	HB	--	--	0	--	--	--	--
			1.20	HB	--	--	1	0	--	--	--
			1.60	HB	130	160	0	0	0	1	--
		ALL	2.38	V-0	130	160	--	--	--	--	--
			3.05	V-0	130	160	--	--	--	0	--

Industrial Laminates:

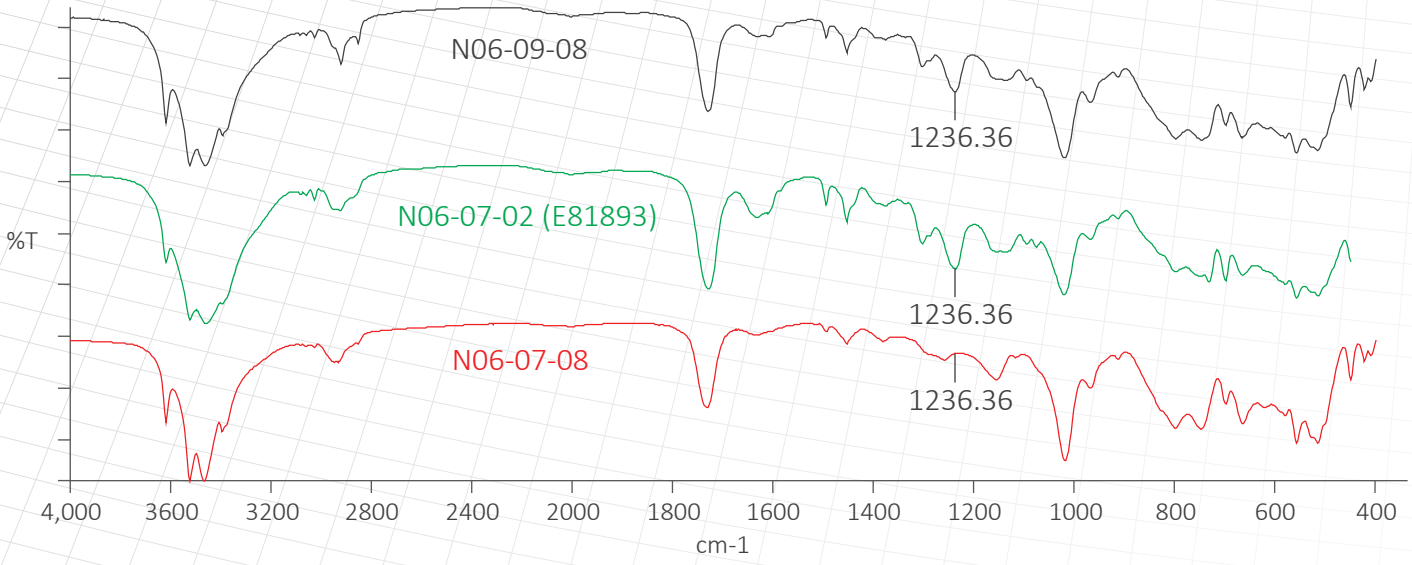
Material Dsg.	ANSI type	Color	Min Thk. mm	Flame Class	RTI Elec.	RTI Mech.	HWI	HAI	HVTR	CTI	Meets 746E DSR
Industrial laminates, furnished as sheets, rods or tubes.											
APO-2	GPO-2	RD	0.71	V-0	90	90	--	0	--	--	--
		RD, WT	1.47	V-0	130	160	--	--	--	--	--
		BK	1.63	V-0	130	160	--	--	--	--	--
		RD, WT, BK	3.05	V-0	130	160	2	--	0	1	--

Table 1.1 – The Gund Company's UL Polymeric Material Certification

There are two issues with infrared analysis from The Gund Company's perspective that make this method less than an ideal process option for adding minor insulation materials to an insulation system:

a) Infrared graphical analysis of one material versus another material is subject to an individual's opinion. Individuals within UL do not always agree on the results of qualitative analysis. Individuals with knowledge of and experience with the chemistry of the materials involved can differ significantly in their opinion of the equivalency of two materials based on infrared analysis.

Figure 1.0 shows an example of an infrared analysis by UL of four grades of GPO-3 material. In their analysis, UL determined that Grade GPO-3 from The Gund Company was equivalent to Glastic® Grade UTR. Additionally, Grade GPO-3 from The Gund Company was equivalent to Haysite® Grade H950. However, UL found enough differences in the chemical signature between Grade GPO-3 from The Gund Company and Haysite® Grade H900 that the materials are not considered equivalent.



d0005327.sp- 06/13/2008- E101063, HAYSITE H 900, N06/09/08, 04, N, F, RD, S
E81893_N100702.dx- 10/21/2002- E81893, H900, N10/07/02, 04, N, F, RD, B
d0005326.sp- 06/13/2008- E101063, GPO3, N06/07/08, 04, N, F, RD, S

b) Infrared analysis only allows a limited number of materials to be added to an insulation system at one time. For example, infrared analysis may be effective for adding one or a few materials that have equivalent chemical signatures. However, this process is completely useless if a given substitute material does not have a UL certified infrared analysis or the same ANSI Type designation in the UL Material Certification database. So, the use of this process in adding minor insulation to a dry type transformer insulation system can be limited.

The Appendix includes a letter from UL confirming equivalent values of various materials allowing them to be used interchangeably in insulation systems.

The table below summarizes the results of the project with UL to determine the equivalency of several glass polyester laminate grades based on infrared analysis.

NEMA Grade	The Gund Company Grades		Other Grade	Based on UL Standard
GPO-1	APO-1	Equivalent To	Glastic® TSF	UL 746A Infrared Analysis
GPO-1	N155	Equivalent To	Haysite® H755	UL 746A Infrared Analysis
GPO-2	APO-2	Equivalent To	Glastic® UTS	UL Material Certification- ANSI Type
GPO-2	APO-2	Equivalent To	Haysite® ETR-FR-II	UL Material Certification- ANSI Type
GPO-3	APO-3	Equivalent To	Glastic® UTR	UL Material Certification- ANSI Type
GPO-3	APO-3	Equivalent To	Glastic® 1580	UL Material Certification- ANSI Type
GPO-3	APO-3	Equivalent To	Haysite® ETR-FR-C Haysite® H900 Haysite® H950	UL Material Certification- ANSI Type
GPO-3	GPO-3	Equivalent To	Glastic® UTR	UL 746A Infrared Analysis
GPO-3	GPO-3	Equivalent To	Glastic® H950	UL 746A Infrared Analysis
GPO-3	GPO-3	Equivalent To	Galstic® UTR	UL 746A Infrared Analysis

2) Sealed Tube Testing – Commonly referred to as chemical compatibility testing, this process cannot be used to establish a new insulation system, but it can be used to add a new minor insulation to an existing insulation system. Sealed tube tests are comparative tests in accordance with ASTM Standard D-5642. The control tube is loaded with only the major insulation materials and conductors (in the form of twisted pairs) used in the electrical insulation system. The candidate tube(s) are loaded with the major insulation materials as well as any additional minor materials to be used in the production of the end product.

   The tubes are sealed and then aged at an elevated temperature, which is based off the thermal class of the electrical insulation system used in the control for 336 hours or two weeks. After the aging process is completed, the twisted pairs of magnet wire are removed and a dielectric breakdown test is performed on them. Each tube will contain between five and ten twisted pairs of each magnet wire type being tested. The results for each tube are averaged. The results for each candidate tube are then compared to that of the control. If the results are within the tolerance established in the standards, then the candidates pass. Note that a successful test does not create a new electrical insulation system; however, it does establish a list of materials that are compatible for use with an already certified system. The sealed tube test evaluates only the interaction of volatile or outgassed components. The end product manufacturer is expected to conduct any other compatibility tests related to the actual application.

The photo above, courtesy of Eltek Labs, shows a typical Sealed Tube with representative samples of materials prior to testing.

The photo above, courtesy of Eltek Labs, shows one tube prior to aging and another tube after aging.

It should be noted that there is a science to sealed tube testing. Eltek Laboratories has conducted thousands of seal tube tests learning several important points worthy of review in the context of this document:

a) Many insulation systems have literally hundreds of materials in their list. However, a common mistake by manufacturers is to include every possible material listed in their system in a sealed tube test. There is a tipping point at which even chemically compatible materials will create enough outgassing activity due to the shear volume of gas generated from more than a hundred samples to cause failure. No system in production will use more than a couple dozen materials in actual production. No system will realistically use more than a few options for each material. To avoid the tipping point of outgassing volume, only employed materials and potentially employed materials should be included in sealed tube testing.

b) One method to limit the number of samples actually included in the sealed tube is to use the infrared analysis method to only include one material from each "chemical family" of products. For instance, 3M® has dozens of electrical insulating tapes that include the same chemistry in terms of resin and substrates that differ only in their thickness. Instead of adding dozens of tapes to the sealed tube, only tape that is representative of the chemical family should be added to the tube. This same concept can be applied to products such as sleeving, flexible laminates, or rigid laminates.

The Gund Company Process

Adding minor insulation materials and components to an existing electrical insulation system does not have to be complicated or time consuming. In fact, our process can be completed within four weeks at no cost with minimum effort if our checklist is followed.

The Gund Company's process for adding minor insulation to a dry type transformer insulation system is based on the following simple points:

» All high voltage electrical insulation systems for dry type transformers are based on the three original systems developed by DuPont®. These three systems are HV-1 (220 °C), HV-2 (220 °C), and HV-3 (180 °C). All other UL high voltage systems in existence are adopted from these original three systems.

» The Gund Company's insulation systems, N180 and N220 are adopted from HV-1, HV-2, and HV-3 with minor insulation materials from The Gund Company added. Any of our customers can adopt our insulation system test results with our permission.

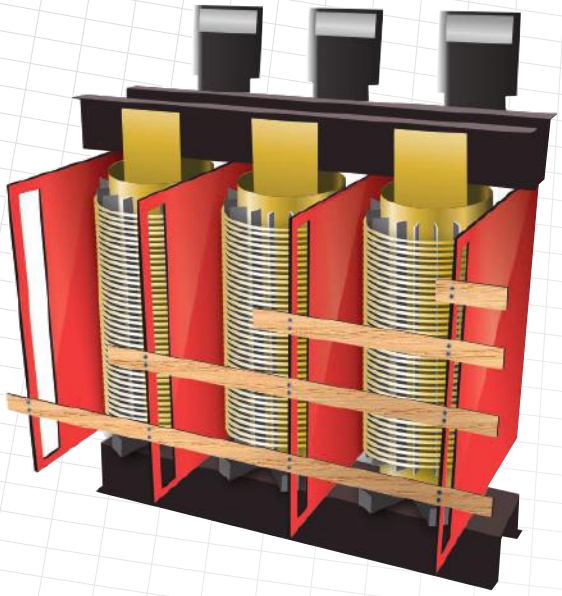
» Because the Sealed Tube Testing Standard ASTM D-5642 referenced in UL 1446 indicates that "the newly proposed materials plus all of the materials currently employed in the insulation system which have the potential to be used in combination with the new materials" must be included in a candidate insulation system, it is important to have each customer provide The Gund Company with a copy of their current UL Insulation System Report section indicating specifically which materials are presently included in their system highlighting which materials are "currently employed" and "have the potential to be used" to make sure those materials are included in N180 and N220.

» For any customers with materials listed on their UL Insulation System report as a Minor insulation list that are not included in The Gund Company's N180 or N220 systems, The Gund Company will be responsible for adding those materials to our system. After adding those materials to The Gund Company's insulation systems, our customers will be able to adopt our system and use The Gund Company's materials in their production process.

THE GUND COMPANY

MANUFACTURERS & FABRICATORS OF ENGINEERED MATERIAL SOLUTIONS

Los Angeles | Milwaukee | Dallas | St. Louis | Cedar Lake | Canada | Mexico | China



This form is provided as a checklist for our customers interested in adding Minor Insulation materials to their electrical insulation system by adopting The Gund Company's N180 and/or N220 insulation system test data reports.

Contact Name:	
Contact Email:	
Contact Telephone:	
Company Name:	

Process Step	Completion Time/Date	Responsible
The Gund Company provides customer with N180 and N220 insulation system report for their review.	Project Start-Up	The Gund Company
Customer provides The Gund Company with the minor insulation section of their UL Insulation System Report and confirms the original Insulation System on which the customer's system is based. (i.e. HV-1, HV-2, HV-3)	Project Start-Up	Customer
Customer and The Gund Company review minor insulation section to confirm materials "currently employed" and/or materials that "have the potential to be used".*	1 Weeks	The Gund Co / Customer
The Gund Company identifies any materials listed in the customer's minor insulation report* that are not included in N180 and N220 insulation systems. If no additional materials or testing is required, Eltek issues a confirmation letter.	2- 3 Days	The Gund Company
If testing is required to add materials to the insulation system, Eltek completes Sealed Tube Testing to add any materials necessary to the N180 and/or N220 insulation systems at The Gund Company's cost.	3 Weeks	The Gund Company
The Gund Company obtains an updated N180 and N220 insulation system report that can be adopted by our customer for the use of The Gund Company Minor insulation materials in their production process.	1 Week	The Gund Company

* It should be noted that many end product Section Generals and customer UL Insulation Systems contain materials that are no longer manufactured. UL rarely cleans up their insulation system material listings to remove materials that are no longer manufactured or widely available. It is recommended that these files are cleansed at this time.

APPENDIX I- UL IR Scan Summary Letter

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Underwriters Laboratories

07/16/2008

The Gund Company Inc.
Mr. Mike Moran
2121 Walton Road
St. Louis, MO 63114

Email: mmoran@thegundcompany.com

Reference..... File: E101063 .....Project: 08NK11130 ..... Volume: 1

Subject..... Comparative Qualitative Infrared Analysis For Several Unsaturated Polyester Composite Materials

Dear Mr. Moran,

Samples of the product itemized below were subjected to infrared analysis with comparative analysis at our Northbrook facility in accordance with the requirements of UL 746A - Standard For Polymeric Materials - Short Term Property Evaluations - Edition 5 - Revision Date 2006-05-30.

For the record, these comparisons were requested to investigate the feasibility for prospective Nohl customers (using UL Recognized Component OBJY@ insulation systems) to substitute minor insulation system components in accordance with substitution criteria outlined in UL 1446, Edition 6 - Revision Date 2008-01-30, Par. 8.2.1.

Criteria for comparative analysis was in accordance with UL 746A, with respect to the UL 746A comparative analysis, comforming results indicate that the compared samples exhibit the same composition within the limits of instrumental detection and the criteria described. Non-conforming results indicate that a compositional variation between compared samples has been observed.

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APPENDIX I- UL IR Scan Summary Letter Cont.

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Underwriters Laboratories

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Below is a summary of our results:

In the comparisons of APO1 from The Gund Company vs GLASTIC® TSF, GPO3 from The Gund Company vs GLASTIC® UTR1494 and GPO3 from The Gund Company vs HAYSITE® H950, The Gund Company grade conformed to the reference grade except for the presence of additional peaks in the reference grade, signifying the presence of additional compounds in the reference grade. Accordingly, grade APO1 from The Gund Company is eligible to be substituted for GLASTIC® TSF grade, grade GPO3 from The Gund Company is eligible to be substituted for GLASTIC® UTR1494 grade and grade GPO3 from The Gund Company is eligible to be substituted for HAYSITE® H950 as minor components of insulation in a previously evaluated insulation system.

Regarding substitution of your materials into your customers' insulation systems, each request will need to be handled on a case-by-case basis.

This along with the attached original datasheet package completes the work anticipated under Project 08NK11130 and we are closing the project with this letter. You will be invoiced for the charges incurred to date. Should you have any questions or comments concerning the above, please feel free to contact the undersigned.

Sincerely,
Bill Buschey
Lead Engineering Associate
william.a.busche@us.ul.com

Reviewed by:
James Joyce
Staff Engineer
james.j.joyce@us.ul.com