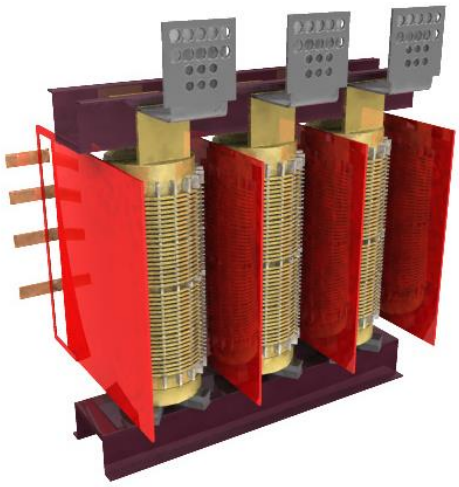
The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

The purpose of this document is to present the process used by The Gund Company to assist our customers in adding equivalent insulation materials to their UL recognized electrical and electronic equipment.

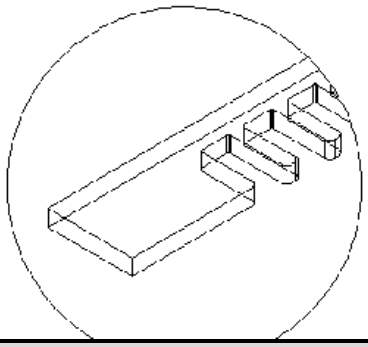
Many manufacturers originally tested their manufactured product to UL, ANSI, or IEEE standards. Those standards often refer to UL Standard 746C – Polymeric Materials: Use In Electrical Equipment Evaluations and/or UL 1446 – Systems of Insulating Materials.

Unfortunately, many older equipment designs and conventions specify insulation material(s) that no longer represent the most advanced material technology on the market today. In fact, many companies have their UL End Product Section General or their material specification pages filled with approved materials that are simply no longer manufactured. Many companies do not realize that they have limited themselves to one or two options despite having a dozen or more materials listed in the Section General.

This document outlines a process for adding equivalent substitute insulation materials to a company's UL Section General or their approved materials list for their manufactured end product based on the process and logic found in UL 746 and UL 1446. This process logic can apply to ANSI and IEEE standards that reference UL Standards 746 and/or UL 1446 regarding insulation material evaluations.



This disc wound dry type transformer shows "winding combs" fabricated from Grade N220 used to support the coil windings.



Dry Type Transformers are one example of electrical equipment that is subject to UL Standards 746 and 1446. These standards outline the requirements for electrical insulation materials; and along with specific end product standards, help design engineers understand the requirements for specified insulation materials.

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Introduction

This document outlines a process for adding equivalent substitute insulation materials to a company's UL Section General or their approved materials list for their manufactured end product based on the logic found in UL 746 and UL 1446. This process logic can apply to ANSI and IEEE standards that reference UL Standards 746 and/or UL 1446 regarding insulation material evaluations.

By including modern material options to their Section General, on their drawings, or in their specifications, companies can increase their sourcing flexibility, shorten their material lead-times, lower their material inventories, and reduce their material costs.

Many companies assume that it is difficult and time consuming to add a new material to their UL files. Unfortunately, UL often gives the standard response that full end product testing is required to add a material to an end product file. By following the process and logic outlined in this document, The Gund Company's customers have easily added material options without end product testing.

I. Understanding UL Standards

Underwriters Laboratories, Inc. was founded in 1894 eventually becoming one of several companies approved to perform safety training and product safety certifications by the US government. UL's original growth was rooted in the development of electrical equipment technologies and corresponding fire prevention initiatives. Today, UL has 64 testing and certification facilities serving customers in 104 countries.

UL coordinates with manufacturers to publish safety Standards for a wide range of equipment, products, and devices. UL then certifies these products as to their compliance with the Standards based on testing protocols established in the Standards. In addition to initial product testing for compliance to the Standard, UL performs an audit service to monitor on-going compliance to the Standards. UL auditors will verify product manufacturing to originally tested and certified designs and product performance parameters.

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UL End Product Standards

UL publishes a wide range of standards that cover most low voltage electrical and electronic equipment. These standards establish the design and testing criteria specifically focused on product safety. As such, the standards typically establish basic performance criteria for electrical insulation. In addition, the performance requirements of plastics used in the design of the equipment are covered by these standards due to the potential for fire from plastics based on the exposure to heat generated by the flow of electricity. UL Standards for electrical and electronic products include:

- UL 67, Standard for Panelboards
- UL 98, Enclosed and Dead-Front Switches
- UL 508, Industrial Control Equipment
- UL 508A, Industrial Control Panels
- UL 508C, Power Conversion Equipment
- UL 845, Motor Control Centers
- UL 891, Switchboards
- UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

Importantly, UL tests and certifies products to their standards. Manufacturers must maintain a file with UL that includes all design drawings and bills of material including the specifications for each material used in the design. UL's on-going audit process includes inspections of a manufacturer's facility to verify that designs, components, and materials used in the tested product are still being used in the manufacturing of that product. These inspections often include pulling a component or material from the product's manufacturing line so that objective evidence of compliance with the original design bill of material and related specifications can be verified. For this reason, manufacturers must be very careful in how they decide to specify materials in their bill of materials and on their drawings.

Often times, a manufacturer will only specify one brand specific material option for an electrical insulation material. If only one brand of a material is specified on the original bill of material, then it can be difficult to get that material changed without UL end product testing. This document will discuss options for updating

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material specifications without UL end product testing. For further information about how best to specify electrical insulation materials, please read The Gund Company's white paper "Writing Specifications for Electrical Insulation Materials."

Most UL standards for electrical and electronic equipment will include references to the material properties required for plastics, polymers, and/or electrical insulation materials. These required material properties are based on UL Standards 746 and 94 which we will introduce in the following pages. It is important to note that each equipment standard covers very specific requirements for these materials which are the common targets for UL auditors seeking to verify compliance to the standard.

For example, a UL End Product Standard, such as UL 67 for Panelboards, typically includes one or more tables which reference the minimum property requirements for insulation materials used in an manufacturer's panelboard end products. An example of such a table from UL 67 appears below:

7 Bases and Supports – Insulating Material

7.1 An insulating material used for direct or indirect support of an uninsulated live part shall provide the level of performance specified in Table 7.1 for direct support and Table 7.2 for indirect support of a live part.

Exception: An insulating material may be accepted based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Table 7.1
Maximum performance level category (PLC) for direct support insulating material

Test specified[a]	Flammability rating of material[a,d]		
	V-0	V-1	V-2
High voltage Arc Tracking Rate (HVTR)	1[b]	1[b]	1[b]
Comparative Tracking Index (CTI) Under Moist Conditions	3[c,e]	3[c,e]	3[c,e]
High Current Arc Ignition (HAI)	3	2	2
Hot Wire Ignition (HWI)	4	3	2

[a] CTI, HAI, HVTR, and HWI are determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Flammability ratings are determined in accordance with the Standard for Tests For Flammability of Plastic Materials For Parts in Device and Appliances, UL 94.
[b] This requirement is only applicable to a component having spacings less than 1/2 inch over surface as covered by Table 14.3.
[c] A material having a comparative tracking index PLC of 4 may be used if the voltage involved is 250 volts or less.
[d] A material having a HB flame rating is not acceptable in any case.

For any material that will be considered for use in the design of the product, it must meet the performance parameters indicated in the standard.

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UL Standards for Plastic, Polymeric, and Electrical Insulation Materials

UL Standards for plastic materials used in electrical and electronic products include:

- UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
- UL 746A, Polymeric Materials: Short-Term Property Evaluations
- UL 746B, Polymeric Materials: Long-Term Property Evaluations
- UL 746C, Polymeric Materials: Use in Electrical Equipment Evaluations
- UL 746D, Polymeric Materials: Fabricated Parts
- UL 746E, Polymeric Materials: Industrial Laminates, Filament Wound Tubing, Vulcanized Fiber and Materials Used in Printed-Wiring Boards
- UL 746F, Polymeric Materials: -– Flexible Dielectric Film Materials for Use in Printed-Wiring Boards and Flexible Materials Interconnect Constructions
- UL 1446, Standards for Systems of Insulating Materials - General

A complete list of UL standards can be found at:

http://ulstandards.ul.com/standards-catalog/?pagesize=1338

The UL 746 series of standards (i.e. 746A, 746B, 746C, etc) establish the process and test methods for evaluating polymeric materials used as electrical insulation materials. UL 94 is the standard that covers the flammability testing for polymeric materials. The standards define critical properties, test methods, and minimum test values. Specific UL End Product Standards such as UL 67 for Panelboards typically reference the UL 746 and UL 94 standards. Importantly, on the basis of the 746 standards, each UL End Product Standard has its own tables establishing the minimum property values for insulation materials used in specific applications.

The ANSI / UL 1446 Standard for Systems of Insulating Materials specifies the test procedure requirements for the evaluation of Class 120C 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.

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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 electro technical device. Though UL 1446 mostly applies to the insulation systems of motors and transformers, the logic for substitution of insulation materials is consistent with the logic found in UL 746.

By following the process and logic of the UL Standards, it is possible to add equivalent insulation materials based on UL Standard 746 that meet the minimum property requirements of each UL End Product Standard without end product testing. First, it is important to understand how UL 746 applies to UL material certifications.

Understanding UL Material Certifications

Consistent with how UL manages end product testing and certification per UL Standards, UL also uses UL 746 to test and certify polymeric materials. Material manufacturers submit polymeric materials to UL or a UL certified laboratory to have the material tested for specific properties.

Prior to the digital age, the test results and corresponding certification was printed on a yellow index card indicating the material manufacturer, the UL File Number, the material grade(s) certified, and the values for each material property tested by UL. These cards were called UL Material Yellow Cards. Today, UL certifications can be found on their website at www.ul.com/database:

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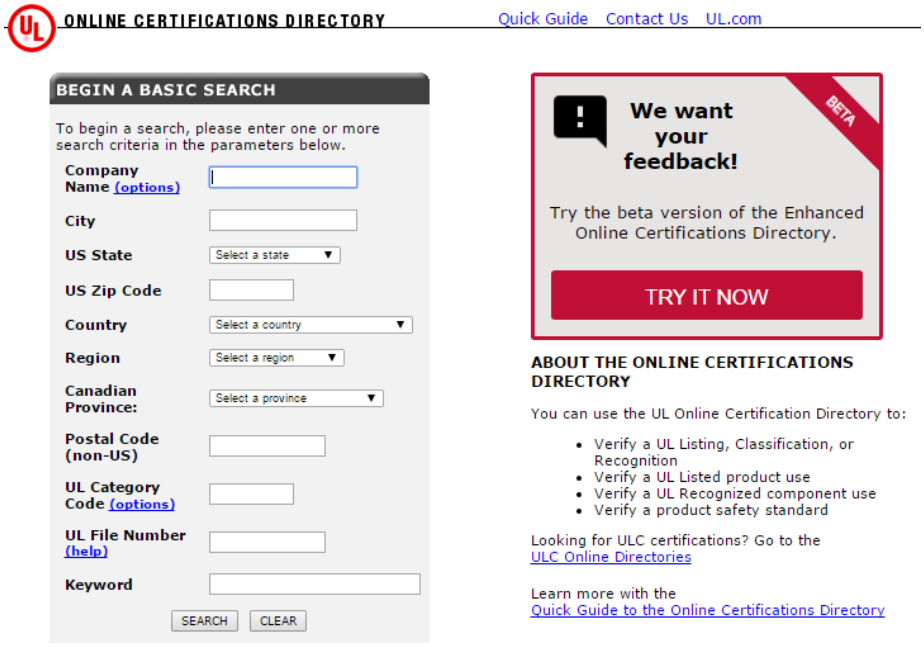

For manufacturers designing equipment made to UL Standards, it is easiest to specify materials that are included in the UL Material Certification database. Because UL Standards will require that the polymeric materials used in the design meet the material properties included in their standard, the easiest way to comply with that requirement will be to use materials already in the UL database. Otherwise, a manufacturer will have to individually and manually prove that each material has been tested to meet the UL material property requirements. By using materials already included in the UL Material Certification program, it is much easy to comply with UL testing requirements.

In addition, by using materials certified by UL, a manufacturer gets the benefit of the UL auditing program for its certified materials. The UL auditing program includes a periodic visit to the manufacturing facility to pull samples for testing which includes both chemical fingerprinting as well as electrical and mechanical testing for property verification. In this way, a manufacturer can have some confidence that a material originally specified and tested to have certain properties will have those properties for as long as the material remains UL certified.

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UL Material Certifications - Short Term Properties

UL Material Certification testing centers around properties that correlate to safety. Thus, there is a heavy emphasis on flame retardance and ignition resistance.

Short term properties are covered by UL94 and 746A and they can be divided into two groups. The first group includes those where a performance level category (PLC) is used. UL uses PLC values to group test results into categories per UL to "avoid excessive level of implied precision and bias" and for easy reference in the End Product Standard property requirement tables.

The most common property values required in UL End Product Standards include:

- UL 94 Flammability Classification (i.e. 5VA, 5VB, V-0, V-1, V-2, HB)
- High Amp Arc Ignition (HAI)
- Hot Wire Ignition (HWI)
- High Voltage Arc Tracking Rate (HVTR)
- Comparative Tracking Index (CTI)

Details of test methodology can be found in these standards but it is important to know that for PLC, a lower the number (i.e. 0 or 1) indicates relatively better performance compared to a high number (i.e. 4 or 5).

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									H	D	
		Min.		H	H	R T I			V	4	C
		Thk	Flame	W	A	Elec	Mech		T	9	T
Material Dsg	Color	mm	Class	I	I		Imp	Str	R	5	I
Polypropylene (PP), flame retardant, furnished as sheets.											
PolyPro FR II	BK, WT	0.23	VTM-0	4	0	110	-	110	0	5	0
		0.40	V-0	4	0	110	-	110			
		0.70	V-0	3	0	110	-	110			
		1.0	V-0	3	0	110	-	110			
		1.5	V-0	3	0	110	-	110			
		2.1	V-0	2	0	110	-	110			
		3.0	V-0	2	0	115	-	115			

Marking: Company name and material designation on container, wrapper or finished part.

Last Updated on 2015-09-28

UL considers certain properties like flammability, hot wire ignition (HWI) and high

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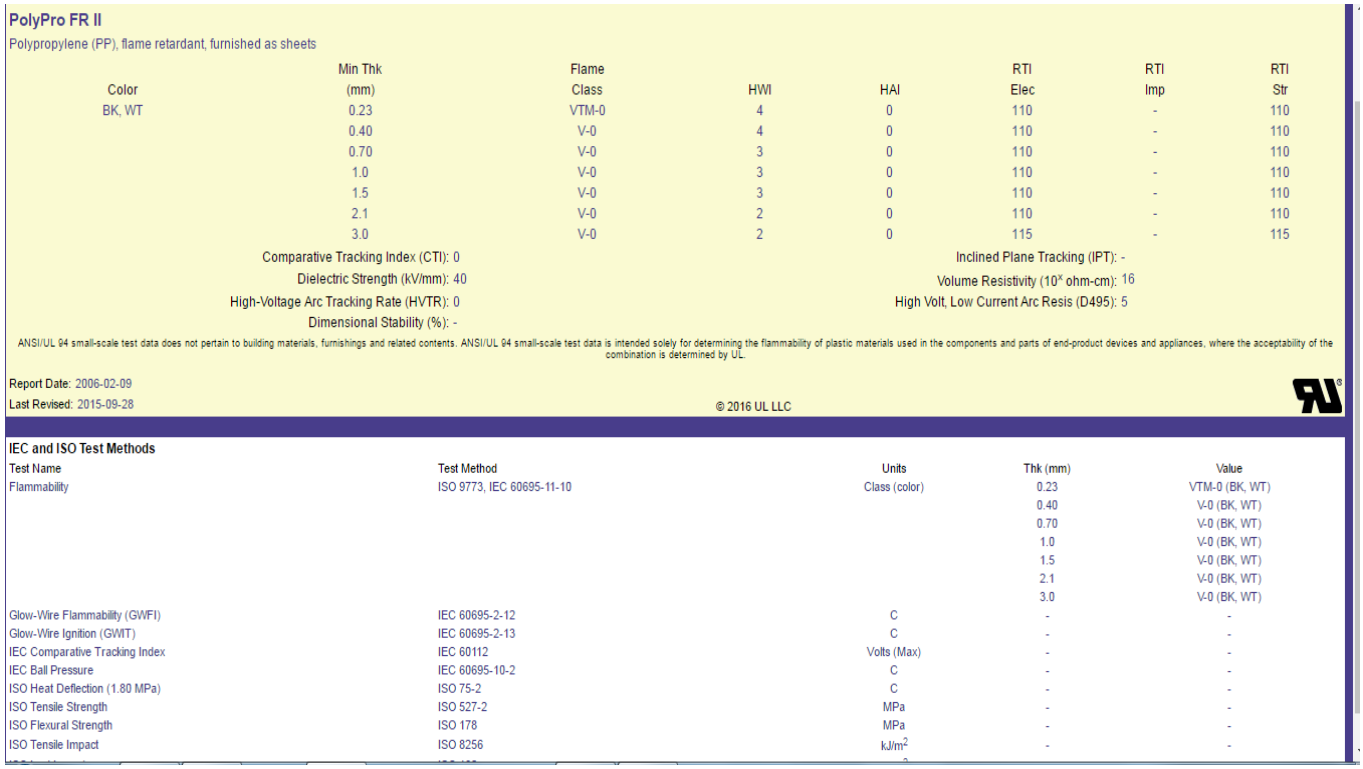
current arc ignition (HAI) to be bulk material property related and the PLC can be extrapolated to higher material thickness, but not lower.

UL also considers some properties like high voltage arc tracking resistance (HVTR), dry arc resistance (D495) and comparative tracking index (CTI) to be more surface property related so the property tested at one thickness can be extended to others. The thickness tested is normally 3 mm.

Sometimes the summary page could be misleading as the one above appears to show HVTR, D495 and CTI tests performed at 0.23mm thickness, but the intent is to show these PLCs cover other thicknesses. If one clicks on the blue PolyPro FR II product code link, there is more detail.



PolyPro FR II

Polypropylene (PP), flame retardant, furnished as sheets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
BK, WT	0.23	VTM-0	4	0	110	-	110
	0.40	V-0	4	0	110	-	110
	0.70	V-0	3	0	110	-	110
	1.0	V-0	3	0	110	-	110
	1.5	V-0	3	0	110	-	110
	2.1	V-0	2	0	110	-	110
	3.0	V-0	2	0	115	-	115

Comparative Tracking Index (CTI): 0
Dielectric Strength (kV/mm): 40
High-Voltage Arc Tracking Rate (HVTR): 0
Dimensional Stability (%): -
Inclined Plane Tracking (IPT): -
Volume Resistivity (10^X ohm-cm): 16
High Volt, Low Current Arc Resis (D495): 5

ANSI/UL 94 small-scale test data does not pertain to building materials, furnishings and related contents. ANSI/UL 94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

Report Date: 2006-02-09
Last Revised: 2015-09-28

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IEC and ISO Test Methods

Test Name	Test Method	Units	Thk (mm)	Value
Flammability	ISO 9773, IEC 60695-11-10	Class (color)	0.23	VTM-0 (BK, WT)
			0.40	V-0 (BK, WT)
			0.70	V-0 (BK, WT)
			1.0	V-0 (BK, WT)
			1.5	V-0 (BK, WT)
			2.1	V-0 (BK, WT)
			3.0	V-0 (BK, WT)
Glow-Wire Flammability (GWFI)	IEC 60695-2-12	C	-	-
Glow-Wire Ignition (GWIT)	IEC 60695-2-13	C	-	-
IEC Comparative Tracking Index	IEC 60112	Volts (Max)	-	-
IEC Ball Pressure	IEC 60695-10-2	C	-	-
ISO Heat Deflection (1.80 MPa)	ISO 75-2	C	-	-
ISO Tensile Strength	ISO 527-2	MPa	-	-
ISO Flexural Strength	ISO 178	MPa	-	-
ISO Tensile Impact	ISO 8256	kJ/m^2	-	-

It is important to note that UL's Material Certification program was designed originally to facilitate material comparison for the purposes of determining design equivalency from a safety perspective. The paragraph below from UL has two critically important sentences highlighted:

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Plastics (QMFZ2) Guide Information

These materials have been tested in accordance with established procedures to define their properties in order to facilitate evaluation of their use in end-use product applications. The tests may include the determination of material flammability (burning characteristics), ignition characteristics from various thermal and electrical sources, electrical tracking and other electrical characteristics, physical and mechanical characteristics, and analytical tests. In addition, the effect of long-term exposure to elevated temperature (air-oven aging), water, ultraviolet light, cold, etc. on property-retention may be evaluated. Due to space limitations, only a limited number of property values may be presented on the individual Recognitions. In those cases where the materials have the same performance characteristics, with the exception of weathering resistance, they are tabulated together as a group with each material designation separated by a comma. These Recognitions may include alternate designations as well as materials that are basically similar in composition but differ by some minor variation, such as molecular weight, lubricants, colorants, etc. Materials within these groupings should be considered equivalent in performance and can be interchanged without additional testing of the end-use product. The colors shown thereon are as pigmented by the material manufacturer; unless otherwise indicated, the property values are for the unpigmented (Natural color) material. Refer to the category Component-Plastics, Flame Retardant and/or Color Concentrates For (QMQS2) and Underwriters Laboratories, Inc. Standard for Polymeric Materials-Fabricated Parts, UL746D for limitations on the use of concentrates by the part molder or processor.

UL Material Certifications - Long Term Properties

With UL's focus on safety, it is logical that UL Standard 746B focuses on the thermal endurance of a polymeric material. In electrical and electronic equipment that build heat due to the resistance of electron flow through conductors, the thermal performance properties of a material are critical. In particular, polymeric materials in "critical applications" that contact live conductors deserve special attention. These materials must maintain their dimensional stability and functional capability both mechanically and electrically when exposed to elevated temperatures.

Thus, UL has established a Thermal Aging Program with a resulting Relative Temperature Index for a material determined by long term testing programs.

The materials covered by this program have, in many cases, been investigated with respect to retention of certain critical properties (e.g. dielectric, tensile, impact, and the like) as part of a long-time thermal-aging program conducted in accordance with UL 746B. The end-of-life of a material at each test temperature in this program has been assumed to be the time when the value of the critical property had decreased to 50 percent of its original (as received) value. If a material has been investigated

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under the thermal aging program, the Relative Temperature Index (RTI), in degrees C shown is based on a comparison with a material which has acceptable service experience and correlates numerically with the temperatures above which the material is likely to degrade prematurely.

If a material has not been investigated under the thermal aging program, the temperature index shown is based on the generic class of the material. A tabulation of the temperature indices according to generic material class is included in UL746B and is based on past field-test performance and chemical structure.

The Relative Temperature Index (RTI) of a material is the maximum service temperature for a material, where a class of critical property will not be unacceptably compromised through chemical thermal degradation, over the reasonable life of an electrical product, relative to a reference material having a confirmed, acceptable corresponding performance defined RTI.

- The RTI Elec is the Electrical RTI, associated with critical electrical insulating properties, most commonly dielectric strength.
- The RTI Mech Imp is the Mechanical Impact RTI, associated with critical impact resistance, resilience and flexibility properties, most commonly tensile impact, Izod impact, or charpy impact.
- The RTI Mech Str is the Mechanical Strength (Mechanical without Impact) RTI, associated with critical mechanical strength where impact resistance, resilience and flexibility are not essential, most commonly tensile or flexural strength.

With UL, once the properties are selected, the material under investigation (candidate) is aged, along with a reference material of known RTI at four different temperatures above the anticipated RTI of the candidate and the RTI of the reference so as to quicken the test duration. UL considers end of life at 60,000 hours with a control reference and 100,000 hours without a control reference. IEC 60216 considers 20,000 hours as end of life.

Regardless of whether it is 20,000, 60,000 or 100,000 hours, running such test for the entire duration is impractical so UL 746B describes methods when RTI can be determined more readily.

With UL 746B, the selected properties are evaluated throughout the test period and the hour at each temperature when 50% loss is reached (F50) is extrapolated or interpolated. The F50 hours are then plotted logarithmically against temperature (Arrhenius curve).

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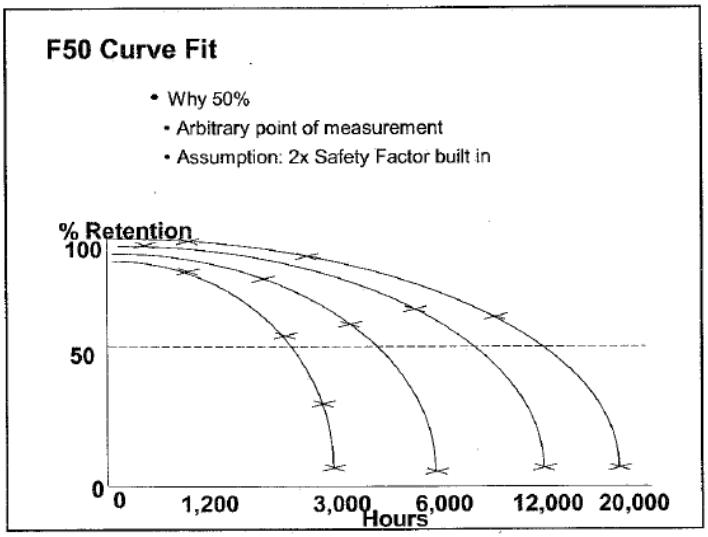
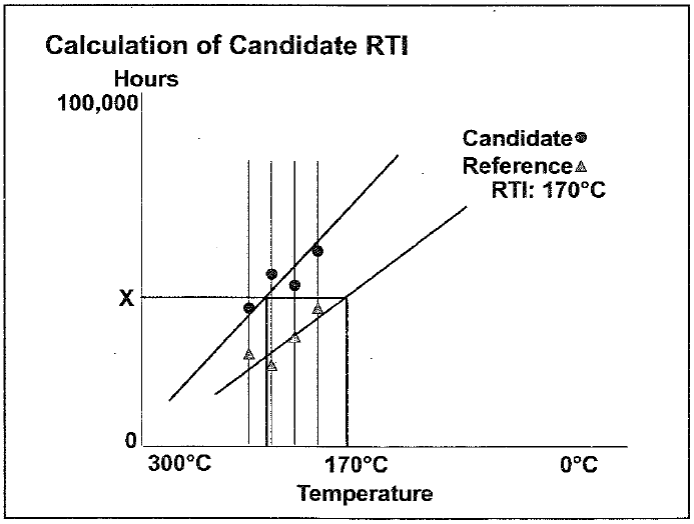
From the RTI temperature of the control, a vertical line is extended to meet the control plot and from which a horizontal line is extended to what should be about 60,000 hours. One then drops a vertical line from where the horizontal line meets the plot of the candidate to obtain the RTI of the candidate. IEC 60216 method is similar but it does not employ a reference and 20,000 hours is used for end of life which could result in a higher RTI.





If a long term RTI test is not conducted, a material receives the default RTI index for the plastic class as per UL 746B Table 7.1 which tends to be conservative.

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Table 7.1
Relative thermal indices based upon past field-test performance and chemical structure[a]

Table 7.1 revised May 30, 2013

Material	ISO designation	Generic thermal index,°C
Polyamide [b]	PA	65
Polycarbonate[b]	PC	80
Polycarbonate/Siloxane Copolymer[k]	PC/Siloxane	80
Polyethylene terephthalate –		
molding resin[b]	PET	75
film (0.25 mm maximum)	PET	105
Polybutylene (polytetramethylene) terephthalate[b]	PBT	75
Polyphenylene Ether (including PS, PA, PP, or TPE modified)[j]	PPE	65
Polypropylene[b,h]	PP	65
Polyetherimide[g]	PEI	105
Polyethersulfone	PES	105
Polyether Ether Ketone	PEEK	130
Polyphenylene Sulfide[b]	PPS	130
Polyimide film (0.25 mm maximum)	PI	130
Molded phenolic[c]	PF	150
Molded melamine[c,d] and Molded melamine/phenolic[c,d] –		
specific gravity < 1.55		130
specific gravity ≥ 1.55		150
Polytetrafluoroethylene	PTFE	180
Polychlorotrifluoroethylene	PCTFE	150
Fluorinated ethylene propylene	FEP	150
Poly(tetrafluoroethylene, hexafluoropropylene, vinylidenefluoride)[l]	TFE/HFP/VDF	130
Ethylene/Tetrafluoroethylene	E/TFE	105
Urea Formaldehyde[c]	UF	100
Acrylonitrile – butadiene – styrene[b]	ABS	60
Silicone – molding resin[c,d]		150
Silicone rubber –		
molding resin	SIR	150
two-component, addition-cure, vinyl, platinum catalyzed		150

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Table 7.1 Continued

Material	ISO designation	Generic thermal index,°C
room-temperature vulcanizing, condensation or heat-cured paste	RTV	105
Epoxy –		
molding resin[c,d]		130
powder coating materials		105
casting or potting resin[b,l]	EP	90
Molded diallyl phthalate[c,d]		130
Molded unsaturated polyester[c,d]	UP	
alkyd (AMC), bulk (BMC), dough (DMC), sheet (SMC),		
thick (TMC), and pultrusion molding compounds		105[e] (electrical) 130 (mechanical)
Liquid crystalline thermotropic aromatic polyester[f]	LCP	130
Ligno-cellulose laminate		60
Vulcanized fiber		90
Cold-molded phenolic, melamine or melamine-phenolic compounds[d] –		
specific gravity< 1.55		130
specific gravity ≥ 1.55		150
Cold-molded inorganic (hydraulic-cement, etc.) compounds		200
Integrated mica, resin-bonded –		
epoxy, alkyd or polyester binder		130
phenolic binder		150
silicone binder		200

[a] Generic thermal index is for homopolymer and for the compounding of the same type or relative resins, either grafted or ungrafted only, unless a specific copolymer or blend is indicated. In the case of alloys, the lowest generic index of any component shall be assigned to the composite. The term "grafted" means all of the monomer reacts to form a polymer, and the polymer chain forms a chemical bond. The term "ungrafted" means that the two types of polymer chains entwine with each other by mechanical blending to form a chemical composite.

[b] Includes glass-fiber reinforcement and/or talc, asbestos, mineral, calcium carbonate, compounding of the same type of resins, either grafted or ungrafted and other inorganic fillers.

[c] Includes only compounds molded by high-temperature and high-pressure processes such as injection, compression, pultrusion, and transfer molding and match-metal die molding; excludes compounds molded by open-mold or low-pressure molding processes such as hand lay-up spray-up, contact bag, filament winding, rotational molding, and powder coating (fluidized bed, electrostatic spray, hot dip, flow coating).

[d] Includes materials having filler systems of fibrous (other than synthetic organic) types but excludes fiber reinforcement systems using resins that are applied in liquid form. Synthetic organic fillers are to be considered acceptable at temperatures not greater than 105°C.

[e] Except 130°C generic thermal index if the material retains at least 50% of its unaged dielectric strength after a 504-hour exposure at 180°C in an air circulating oven. Specimens are to be tested in a dry, as molded, condition. Specimens that are removed from the oven are to be cooled over desiccant for at least 2 hours prior to testing.

[f] Includes only wholly aromatic liquid crystalline thermotropic polyesters; wholly aromatic polyester/amides and wholly aromatic polyester/ethers; excluding amorphous, lyotropic and liquid crystalline aliphatic-aromatic polyesters which are aliphatic in the backbone chain or main chain, and substituted aromatic polyesters (except for methyl or aromatic).

[g] Includes only polyetherimide molding resin.

[h] Includes polypropylene copolymers containing not more than 25% ethylene comonomer, by weight.

[i] Multi-part liquid epoxy materials incorporating acid anhydride or aromatic amine curing agents receive a 130°C generic thermal index.

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II. Process for Equivalent Material Substitution – Generic Applications

Having provided a good understanding of UL Standards and their impact on material selection, the process for substitution of equivalent polymeric materials can be reviewed in detail.

For many applications in a given design, the substitution of material can be quite simple. Depending on the design, there can be a determination of the generic versus critical application of a particular material. Typically, this determination is made in coordination with a UL Engineer based on the function of a particular material or component. Applications where there is no direct contact with a conductor are generally considered generic. Applications where is there is direct contact with a conductor are generally considered critical.

UL End Product Standard Requirements Review -

The first step in the process to determine if an equivalent material may be substituted in a given design starts with understanding the UL End Product Standard requirements for polymeric materials. For many UL Standards, there is a specific table of requirements for polymeric or insulation materials.

For example, a UL End Product Standard such as UL 67 for Panelboards typically includes one or more tables which reference the minimum property requirements for insulation materials used in a manufacturer's panelboard end products. An example of such a table from UL 67 appears below:

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7 Bases and Supports – Insulating Material

7.1 An insulating material used for direct or indirect support of an uninsulated live part shall provide the level of performance specified in Table 7.1 for direct support and Table 7.2 for indirect support of a live part.

Exception: An insulating material may be accepted based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Table 7.1
Maximum performance level category (PLC) for direct support insulating material

Test specified[a]	Flammability rating of material[a,d]		
	V-0	V-1	V-2
High voltage Arc Tracking Rate (HVTR)	1[b]	1[b]	1[b]
Comparative Tracking Index (CTI) Under Moist Conditions	3[c,e]	3[c,e]	3[c,e]
High Current Arc Ignition (HAI)	3	2	2
Hot Wire Ignition (HWI)	4	3	2

[a] CTI, HAI, HVTR, and HWI are determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Flammability ratings are determined in accordance with the Standard for Tests For Flammability of Plastic Materials For Parts in Device and Appliances, UL 94.
[b] This requirement is only applicable to a component having spacings less than 1/2 inch over surface as covered by Table 14.3.
[c] A material having a comparative tracking index PLC of 4 may be used if the voltage involved is 250 volts or less.
[d] A material having a HB flame rating is not acceptable in any case.

For any material that will be considered for use as an equivalent substitute of an existing material, the substitute product must meet the performance parameters indicated in the standard.

UL 746C indicates that specific end product Performance Level Categories are established in Table 6.1 and may be covered in specific UL End Product Standards such as UL 67:

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The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

ELECTRICAL INSULATION

6 Material Property Considerations

6.1 General

6.1.1 Mechanical and electrical properties of materials are to be judged with respect to the particular "end use" application. The requirements in this section establish general minimum requirements for applications where the polymeric material is relied upon to reduce the risks of fire and electric shock.

6.1.2 These requirements do not cover the additional considerations that must be given to applications employing large masses of polymeric materials. Whether or not such materials protect against electric shock or injury to persons, consideration is to be given to the likelihood of ignition of the material by sources inside the product or by sources outside the product. See Section 19 for Flame Spread requirements to be applied to large mass applications.

All materials proposed as equivalent substitutes by The Gund Company meet the Performance Level Category specifications as listed in UL 746C and applicable UL End Product Standards.

UL 746C does establish that end product testing could be required if a material does not meet a specified Performance Level Category established in the applicable standard:

6.2 Evaluation of Materials Not Meeting Preselection Test Performance Levels in Table 6.1

6.2.1 Some materials may have performance characteristics less than the minimum required for the construction type (Figurative example) in Table 6.1. In such cases, the application can be considered in the context of the complete end product construction and special tests conducted to determine if the lower value can be accepted without increasing the likelihood of risk for the particular end-product.

6.2.2 Table 6.2 indicates which end-product tests, or other considerations such as increased thicknesses or spacings, may be used as alternatives to the requirements in Table 6.1.

However, because all materials proposed as equivalent substitutes by The Gund Company meet the Performance Level Category specifications in the applicable standards, UL does not require end product testing. No UL Standard establishes the requirement for end product testing based on the substitution of equivalent polymeric materials. End product testing is not required when substituting equivalent polymeric materials.

<u>Comparison of UL Material Listing Property PLC Values -</u>

Based on the test methods outlined in UL 746 and the End Product insulation

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material performance tables established in a particular standard, a comparison of existing versus proposed equivalent substitute material properties should be completed.

Again using the UL 67 example, the table below summarizes the required performance levels for insulation materials as specified in UL 67 Table 7.1 and 7.2. Though some materials may have different performance levels for various properties, they all meet the requirements of the standard.

Insulating Material for Sole Support of Current-Carry Parts (Note: Only present day available sheet materials included. Fabricated, not molded sheet materials.)

a) Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	UL RTI Value	Minimum Thickness	HVTR	CTI	HAI	HWI
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	130C	1/16"	0	0	0	1
NEMA GPO-3	Haysite	GPO-3	H950	160C	1/16"	0	0	0	0
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	130C	1/16"	0	0	0	1
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	130C	1/16"	0	1	0	0
NEMA GPO-2	PolyPly	GPO-2	L-40	130C	1/16"	2	0	2	1
b) Material Options To Add									
NEMA GPO-3	Haysite	GPO-3	H900	130C	1/16"	0	0	0	1
NEMA GPO-3	Gund	GPO-3	GPO-3	130C	1/16"	0	0	0	1
NEMA GPO-3	Gund	GPO-3	APO-3	130C	1/16"	0	1	1	2
NEMA GPO-2	Gund	GPO-2	APO-2	130C	1/16"	0	1	0	2

The test property values indicated in the summary chart above come from the UL Material Certifications Directory. UL Standard 746 establishes the UL Material Certification program that includes UL testing of certified materials with annual auditing to verify on-going compliance. Every material that has a UL Material Certification file can be found in the UL Material Certifications Directory on-line (www.ul.com/database). An example of a typical material certification (historically called a "yellow card") can be found below.

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									H	D	
		Min.		H	H	R T I			V	4	C
		Thk	Flame	W	A	Elec	Mech		T	9	T
Material Dsg	Color	mm	Class	I	I		Imp	Str	R	5	I
Unsaturated Polyester (UP), glass reinforced, furnished as sheets and various profiles.											
GPO-3	ALL	0.9	HB	3	0	-	130	130	0	4	0
		1.7	HB	1	0	130	130	130			
		3.1	V-0	0	0	130	130	130			

Marking: Company name and material designation on container, wrapper or finished part.

Last Updated on 2016-02-25

Based on an evaluation of the insulation material properties as required in a particular End Product Standard and a corresponding comparison of existing approved material properties versus equivalent substitute materials, it can be determined if the substitute materials meet the requirements of the standard.

In addition to a comparison of the material properties based on the UL Material Certification Program, additional material properties may be compared to establish confidence in the equivalent performance of the materials in application. For example, the table below compares the properties of 5 approved materials already used in an end product to 4 equivalent substitute materials.

Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	NEMA Standard Flexural Strength (psi)	Grade Data Sheet Flexural Strength (psi)	Grade Data Sheet Compressive Strength (psi)	Grade Data Sheet Tensile Strength (psi)	Grade Data Sheet Impact Strength ft-lb/in
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	18,000	22,100	33,000	7,800	8.9
NEMA GPO-3	Haysite	GPO-3	H950	18,000	25,000			
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	18,000	24,600	39,000	8,900	10
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	18,000	21,000	30,000	10,000	8
NEMA GPO-2	PolyPly	GPO-2	L-40	18,000	22,000	32,000	9,800	9.8
Material Options To Add								
NEMA GPO-3	Haysite	GPO-3	H900	18,000	18,000	30,000	9,000	8
NEMA GPO-3	Gund	GPO-3	GPO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-3	Gund	GPO-3	APO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-2	Gund	GPO-2	APO-2	18,000	22,000	37,000	9,000	9

Though material test property values may vary slightly, each of the materials listed belong to the same chemical composition families, which results in a very

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tight pattern of testing results.

The same logic for substitution of equivalent thermoset glass polyester laminates applies to thermoplastic flame retardant polypropylene materials which are also commonly used in electrical and electronic equipment.

For example, there are two flame retardant polypropylene sheet materials in the market today: Formex and PolyPro FR. Below are the UL Material Certifications for PolyPro FR and Formex material:

PolyPro FR II

Polypropylene (PP), flame retardant, furnished as sheets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
BK, WT	0.23	VTM-0	4	0	110	-	110
	0.40	V-0	4	0	110	-	110
	0.70	V-0	3	0	110	-	110
	1.0	V-0	3	0	110	-	110
	1.5	V-0	3	0	110	-	110
	2.1	V-0	2	0	110	-	110
	3.0	V-0	2	0	115	-	115

Comparative Tracking Index (CTI): 0
Dielectric Strength (kV/mm): 40
High-Voltage Arc Tracking Rate (HVTR): 0
Dimensional Stability (%): -
Inclined Plane Tracking (IPT): -
Volume Resistivity (10^X ohm-cm): 16
High Volt, Low Current Arc Resis (D495): 5

ANSI/UL 94 small-scale test data does not pertain to building materials, furnishings and related contents. ANSI/UL 94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

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IEC and ISO Test Methods

Test Name	Test Method	Units	Thk (mm)	Value
Flammability	ISO 9773, IEC 60695-11-10	Class (color)	0.23	VTM-0 (BK, WT)
			0.40	V-0 (BK, WT)
			0.70	V-0 (BK, WT)
			1.0	V-0 (BK, WT)
			1.5	V-0 (BK, WT)
			2.1	V-0 (BK, WT)
			3.0	V-0 (BK, WT)
Glow-Wire Flammability (GWFI)	IEC 60695-2-12	C	-	-
Glow-Wire Ignition (GWIT)	IEC 60695-2-13	C	-	-
IEC Comparative Tracking Index	IEC 60112	Volts (Max)	-	-
IEC Ball Pressure	IEC 60695-10-2	C	-	-
ISO Heat Deflection (1.80 MPa)	ISO 75-2	C	-	-
ISO Tensile Strength	ISO 527-2	MPa	-	-
ISO Flexural Strength	ISO 178	MPa	-	-
ISO Tensile Impact	ISO 8256	kJ/m^2	-	-

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FORMEX GK-(a)(b)(f2)

Polypropylene (PP), furnished as sheets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
ALL	0.05	VTM-0	4	0	115	-	115
	0.10	VTM-0	4	0	115	-	115
	0.20	VTM-0	4	0	115	-	115
	0.37	V-0	4	0	115	-	115
	0.71	V-0	4	0	115	-	115
	3.0	V-0	1	0	115	-	115
NC, BK	0.0508	VTM-0	4	0	115	-	115
	0.254	VTM-0	4	0	115	-	115

Comparative Tracking Index (CTI): 0
Dielectric Strength (kV/mm): 42
High-Voltage Arc Tracking Rate (HVTR): 0
Dimensional Stability (%): 0
Inclined Plane Tracking (IPT): 232 min at 1.5kV
Volume Resistivity (10^x ohm-cm): 15
High Volt, Low Current Arc Resis (D495): 6

(a) - One to three digit suffix indicating nominal thickness in mils.
(b) - One to two digit suffix indicating nominal thickness in mils (7~10 mils)
(f2) - Subjected to one or more of the following tests: Ultraviolet Light, Water Exposure or Immersion in accordance with UL 746C, where the acceptability for outdoor use is to be determined by UL.
NOTE - HVTR, CTI and D495 are thickness independent

ANSI/UL 94 small-scale test data does not pertain to building materials, furnishings and related contents. ANSI/UL 94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

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IEC and ISO Test Methods

Test Name	Test Method	Units	Thk (mm)	Value
Flammability	ISO 9773, IEC 60695-11-10	Class (color)	0.05	VTM-0 (ALL)
			0.10	VTM-0 (ALL)
			0.20	VTM-0 (ALL)
			0.37	V-0 (ALL)
			0.71	V-0 (ALL)
			3.0	V-0 (ALL)
			0.0508	VTM-0 (NC, BK)
			0.254	VTM-0 (NC, BK)
Glow-Wire Flammability (GWFI)	IEC 60695-2-12	C	-	-

By comparing the PLC values of these materials, it is quickly apparent that these two materials have equivalent properties. Where there are small differences, they are largely inconsequential in terms of compliance to the requirements of typical UL End Product Standards such as UL 67, UL 98, UL 508C, and UL 1741. For example, at 3.0 mm, PolyPro FR has an PLC value of 2 for HWI while Formex has a PLC value of 1. Both are very highlighted rated and no UL Standard requires a higher value for a UL 94 V-0 rated material. Similarly, the PLC value for PolyPro FR is a 5 for D495 while Formex has a PLC value of a 6.

As a bit of foreshadowing, UL has concluded that these materials are equivalent based not only upon their similar PLC values, but based on a comparison of their chemical fingerprint references.

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Special Process for Adding New Recognized Component Plastic

This type of situation is very unique and would not involve any additional testing. In a situation where it is known that an alternate polymeric material is identical in composition and construction with identical Recognized (QMFZ2) properties to an existing material that has already been fully tested, no end product testing would be required. This direct acceptance applies to the addition of PolyPro FR by The Gund Co., under file E228440, in applications where the Formex material by Illinois Tool Works, under file E121855, has been previously accepted.

See Appendix C for the full letter from UL on the equivalency of Formex and PolyPro FR materials.

Comparison of Chemical Fingerprint References (IR, DSC, and TGA) -

During the initial testing for the UL Certification of a polymeric material, IR (infrared), DSC (differential Scanning Calorimetry) and TGA (Thermal Gravity Analysis) scans are performed. These are the chemical composition fingerprints of the material. This information is maintained by UL as reference in a UL file hidden from public view, see example below.

File E228440 Vol. 1 (File behind Appendix D) Sp. App. B Page 1 Issued: 2011-11-14 Revised: 2013-01-18

COMPONENT - PLASTICS (QMFZ2, QMFZ3, QMFZ8, QMFZ9)

TABLE B - INDEX TO TESTING

Sample Group	#/Group /Year	Generic Class	Material Designation	Report Date	Thk, mm	Color	Flame	IR Ref	TGA Ref	DSC Ref	GC Ref	Additional Info	Test Program Code
1	1	Polypropylene (PP)											
			PolyPro FR (f2)	2002-06-07	0.20	BK	V-0	M05-12-86(E51346)	02-07-98(E51346)	05-24-86(E51346)	-	-	B
					0.41	BK	V-0	M05-12-86(E51346)	02-07-98(E51346)	05-24-86(E51346)	-	-	B
					0.75	ANY	V-0	M05-12-86(E51346)	02-07-98(E51346)	05-24-86(E51346)	-	-	B
			PolyPro FR II	2006-02-09	0.23	BK WT	VTM-0	N01-06-06(E84658)	01-07-06(E84658)	N01-10-13$	-	$ second heat DSC	D
					0.70	BK WT	V-0	N01-06-06(E84658)	01-07-06(E84658)	N01-10-13$	-	$ second heat DSC	B

The material chemical composition fingerprint is used in two ways.

First, during factory follow-up service of a UL certified material, a sample of the

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current production is taken by the UL field inspector for IR, DSC and TGS scans to be performed at a UL laboratory. UL 746E, Appendix A establishes the process for the annual audit or "follow up testing" for materials covered in the UL material certification program. The scans of the current production are then compared to the reference to ensure compliance.

Second, the reference fingerprint scans can also be used in evaluating the direct substitution or addition of an equivalent material situation. The language from UL 746E is copied below:

APPENDIX A

Infrared (IR) Analysis Conformance Criteria for Follow-Up Testing and Revision to Materials

A1 Background & Purpose:

A1.1 Infrared (IR) spectroscopy is one of the identification tools used to analyze a wide variety of materials. When samples are received under the original investigation, they are subjected to IR testing in order to establish a "reference spectrum." This spectrum is considered to be qualitatively representative of the sample tested. The reference spectrum is retained for future comparison purposes.

A1.2 This document provides a description of the criteria applied in comparative analysis of IR spectra for all product categories. The existence of product category-specific conformance criteria would supersede this document. Conforming results indicate that the current sample exhibits the same composition within the limits of instrumental detection and the criteria described herein. Non-conforming results indicate that a compositional variation in the current sample has been observed.

A typical IR scan for a NEMA GPO-2 material appears below:

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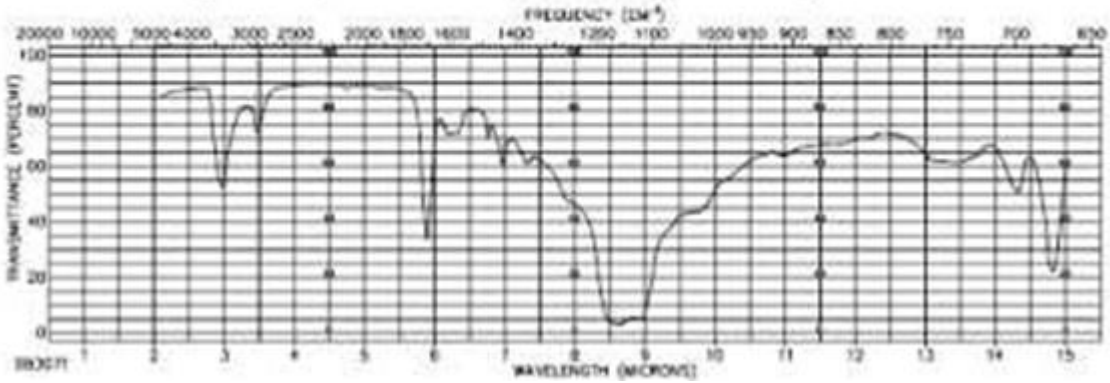
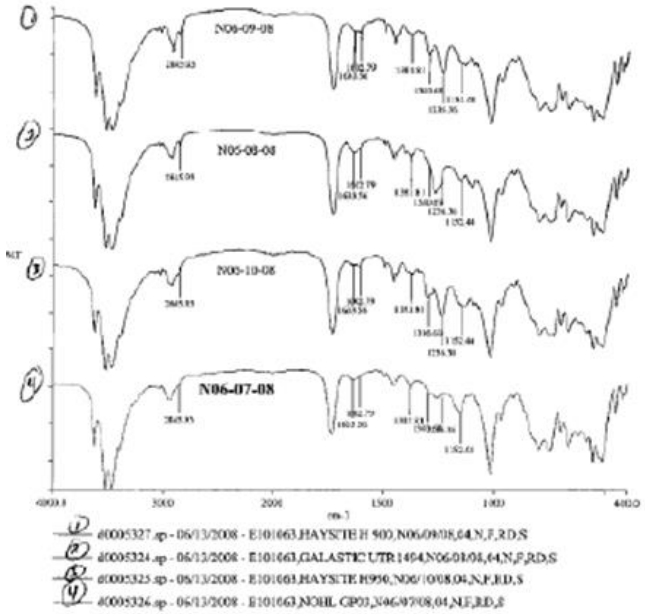
Figure D1.28
Typical IR spectrum for industrial laminates UL/ANSI Type GPO-2



The Gund Company has completed extensive chemical composition fingerprint testing with UL to determine equivalency of various materials. In the example below, testing was completed on a series of rigid, low pressure glass polyester laminates. The IR scan data below is an example of chemical composition fingerprint testing for NEMA GPO-3 materials:



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The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

As noted in UL 746E, Appendix A1.2, product category specific conformance criteria exists for certain grades or "ANSI Type" materials such as the NEMA GPO-2. For grades of materials with product category or ANSI type designations, their equivalency is noted on the UL Material Certification for a particular grade.

In the UL Material Certification table below, note that the Nohl Grade APO-2 has an ANSI Type designation of GPO-2 meaning that it complies with the IR scan spectrum for ANSI / NEMA GPO-2 material as having "equivalent" chemical composition and would be considered to be an "equivalent material" to other grades with the same ANSI Type designation.

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E75481

Mtl Dsg	ANSI Type	Col	Min Thk		TI		HWI	UL94 Flame Class	HAI	HVTR	D-495	CTI
			In.	(mm)	Elec	Mech						
Industrial laminated sheet, rod or tube form.												
APO-2	GPO-2	BD	0.028	(0.71)	90	90	—	V-0	145	—	—	—
		BD,WH	0.058	(1.47)	130	160	—	V-0	—	—	—	—
		BE	0.064	(1.63)	130	160	—	V-0	—	—	—	—
		BD,BE, WH	0.120	(3.05)	130	160	50	V-0	—	0.070+	187	500+
APO-3	GPO-3	BD	0.028	(0.71)	90	90	38	—	68	—	—	—
		BD, WT	0.058	(1.47)	120	140	—	V-0	—	—	—	—
		BD, BE	0.064	(1.63)	120	140	—	V-0	—	—	—	—

Thus, substitute material options can easily be determined to be equivalent to an existing material in use or previously approved by referencing the ANSI Type designation on the UL Material Certification.

For grades of material that may not have an ANSI Type designation on the UL Material Certification, the same process logic can be used. By having an IR scan performed, various materials can be compared to determine their chemical composition equivalency.

As a result of this testing, UL issued a letter found in the Appendix D with results summarized in the table below:

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NEMA Grade	Gund Grade	[redacted]	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 1580	UL Material Certification – ANSI Type
GPO-3	APO-3	Equivalent To	Glastic UTR 1580	UL Material Certification – ANSI Type
GPO-3	APO-3	Equivalent To	Haysite ETR-FR-C Haysite H900	UL Material Certification –
			Haysite H950	ANSI Type
GPO-3	GPO-3	Equivalent To	Glastic UTR 1494	UL 746A Infrared Analysis
GPO-3	GPO-3	Equivalent To	Glastic H950	UL 746A Infrared Analysis
GPO-3	GPO-3	Equivalent To	Glastic UTR 1494	UL 746A Infrared Analysis

For generic applications in most designs, one or all of the steps above may be necessary to obtain approval from UL to add an equivalent material to a drawing, a UL file, or a UL End Product Section General. Frankly, the UL Material Certification program was created for this exact purpose, in part.

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III. Process for Equivalent Material Substitution – Critical Applications

As noted previously, there are some applications in some designs that a UL Engineer may consider to be critical in nature typically because a material is in direct contact with a conductor of electricity. For these applications, a UL Engineer may require additional material testing to determine equivalency. Material testing is far less expensive than end product testing. The Gund Company has completed exhaustive testing with UL as documented in the Appendix.

UL Directed Material Testing in Lieu of End Product Testing

Despite the options available and outlined as Steps 1, 2, and 3 above, there are rare cases when an UL Engineer has wanted additional material testing. In each case historically where we encountered this situation, a single material was specified by the manufacturer when the product was end product tested by UL. Not knowing why only one specific brand of a given product was specified, a UL Engineer tends to take a conservative approach in requesting some head-to-head comparative material testing.

One example of a critical application that is fairly typical involved a glass polyester laminate used as a bus bar conductor support in a Motor Control Center manufactured to the UL 845 Standard. The manufacturer's drawing only referenced a brand specific material grade, Glastic NEMA GPO-3, Grade UTR. It is likely, but unknown, whether this was the only grade tested during UL End Product Testing per the standard. In order to reduce supply chain risk, shorten lead-times, and improve costs, The Gund Company was challenged to work with UL to obtain equivalent material options without costly end product testing that could cost well into six figures.

In order to obtain the approval of Gund NEMA GPO-3 material, there was significant coordination between the manufacturer, UL, and The Gund Company. As part of the review, the following was confirmed by UL:

- Gund NEMA GPO-3 met the requirements of UL 845.
- Gund NEMA GPO-3 had equivalent or better UL Material Certification PLC values relative to Glastic, NEMA GPO-3, Grade UTR per UL 746.
- Gund NEMA GPO-3 had an equivalent chemical composition fingerprint per UL 746.

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Because the application was in direct contact with a conductor and in an application requiring mechanical support of a busbar, it was agreed that head-to-head impact tensile testing would be done by UL's laboratory.

Appendix E includes a letter from a UL Material Engineer from their testing laboratory indicating the equivalent performance of "Candidate A" - Gund NEMA GPO-3 relative to the "Legacy" – Glastic NEMA GPO-3, Grade UTR as noted below:

> *The "candidate "A"" material performed equal to or better than the "legacy" material with respect to the tensile impact tests conducted. The candidate material is eligible for consideration for material substitution in lieu of certain end product tests for critical applications such as bus bar support (UL 845, Motor Control Centers) - short circuit failure.*

The Gund Company paid the cost of this testing to UL so results may be shared with our customers for their similar critical application testing.

Material Substitution by Electrical Insulation System (EIS) Modification

The UL 1446 standard also establishes the process (Section 14 and Section 15) for adding a new insulation material or component to an existing insulation system. It is beyond the scope of this document to detail how insulation materials can be added to equipment using an insulation system such as motors and transformers though The Gund Company has written a specific paper on the topic that is available on our website. UL 1446 does affirm the use of the IR scan process for confirming material equivalency.

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

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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."

In the cases where a group of materials need to be added to an established electrical insulation system in equipment manufactured to a UL End Product Standard that references UL 1446, UL testing must be performed to ensure the candidate materials are chemically compatible with the incumbent materials and do not cause premature failure under prolonged exposure to the system's rated hot spot temperature class. The most common applications for insulation systems subject to UL 1446 include electric motors and transformers.

If the materials to be added are minor components, a sealed tube test is conducted where samples of candidate materials to be considered are aged along with the incumbent materials for 2 weeks at 25C above the thermal class of the system along with a control tubes whose loading is determined by UL based on the original Electrical Insulation System (EIS) at the top of the family tree (i.e., DuPont HV1, HV2...). The dielectric strength of the insulated conductors in the candidate tube shall be at least 50% that of the control tube (if the same pool of conductors – magnet wire - are used and previously tested to be statistically identical). If the candidate and reference tubes use different insulated conductors, a factored ratio method is used.

It is important to realize that the control tube is usually comprised of one representative of each type of insulation in the winding coil construction (i.e. sleeve, tape, spacer). It is important to be careful not to include in the candidate tubes any materials no longer used in production as this increases the likelihood of test failure as the control tube may easily outperform the candidate tube based on its lighter loading. A rule of thumb is to load the candidate tube with no more than 50 components and use class representative materials as much as possible. For examples, UL allows Nomex 410 to represent all Nomex. Similarly, certain 3M tapes may represent a group of tape.

If the EIS changes involve major insulation, a full thermal aging with at least three different temperatures shall be used against a known reference to determine the new thermal class of the modified EIS using the methodology described previously in this document. However, a motorette which is a non-functional assembly including all candidate and representative incumbent materials are used, along with a control

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motorette of known thermal class. In some case, a scale down but functional unit, i.e., modelette (scale down transformer coil) needs to be used.

Whether a sealed tube test or a motorette based insulation system test, adding a new substitute per UL 1446 is still much easier than end product testing. The Gund Company can work with customers to determine the best option for adding equivalent polymeric materials for their equipment designs manufactured to UL Standards.

IV. Turn Key Process – UL 37 Agency Agreement

The Gund Company is willing to assist its customers to update their drawings, specifications, and UL files to add new materials or replace old materials. Our white paper "Writing Specifications for Electrical Insulation Materials" may help our customers determine some best practices that will help avoid issues with UL certification and compliance. We have many years of experience working with UL on polymeric material listing under UL746; Electrical Insulation System modification under UL1446, as well as component listing under various end product standards such as UL891 Switchboards. We have worked with major OEMs and assist them with their work on their UL end product. We also have the laboratory resource to conduct screening tests.

We are prepared to offer our valued customer a turn-key service, where the execution of a UL L37 agreement would allow us to work as a confidential agent and deal with UL on behalf of our customers on all matters relating to the update of the UL file. Depending on the business opportunities, we will share or even assume the UL fees involved. Our customer maintains full ownership of their UL files through the entire period of agency.

The L37 agreement is confidential to the three parties involved, TGC, customer and UL. It has several options and can be tailored to have a limited scope and duration. Usually, we will cease to be the UL agent at project completion upon issuance and review of UL letter of authorization.

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The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

Summary

The Gund Company has extensive experience in working with both manufacturers and UL to easily substitute equivalent materials in equipment made to UL Standards that may have been UL End Product Tested with either sole specified materials, outdated materials, or risky supply chain sources. By helping customers update their historical specifications, The Gund Company can help customers lower their costs, shorten their lead-times, and reduce their supply chain risk.

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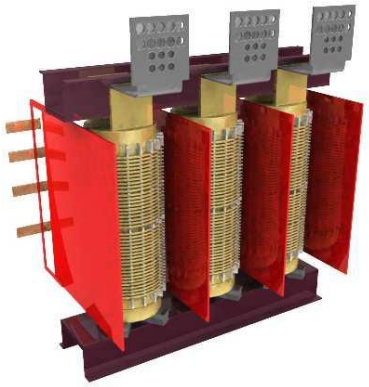
The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

This form is provided as a checklist for our customers interested in adding equivalent substitute insulation materials to their equipment designs.



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

Process Step	Completion Time / Date	Responsible
OEM provides TGC with the UL / ANSI / IEEE Standard applicable to their product as well as copies of any sections including insulation material performance requirement tables.	Project Start-Up	Customer
If applicable, customer provides TGC with copy of existing end product Section General if a comparison of existing materials versus proposed equivalent material is desired.	Project Start-Up	Customer
a) TGC evaluates the standard and provides a list of potential substitute materials. b) TGC summarizes property value requirements as well as typical property values for existing versus proposed equivalent materials. c) TGC summarizes the logic based on UL 746 and UL 1446 for substitute material approval by UL with no end product testing.	1 - 2 Weeks	TGC
TGC provides a copy of this document as well as the summary report for OEM to share with UL field inspector for approval of substitute materials.	1 Week	TGC
Customer works with UL to add equivalent substitute materials to their UL Section General (as required).	2 - 4 Weeks	TGC or Customer

* Note 1: 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 recommend that these files are cleansed at this time.

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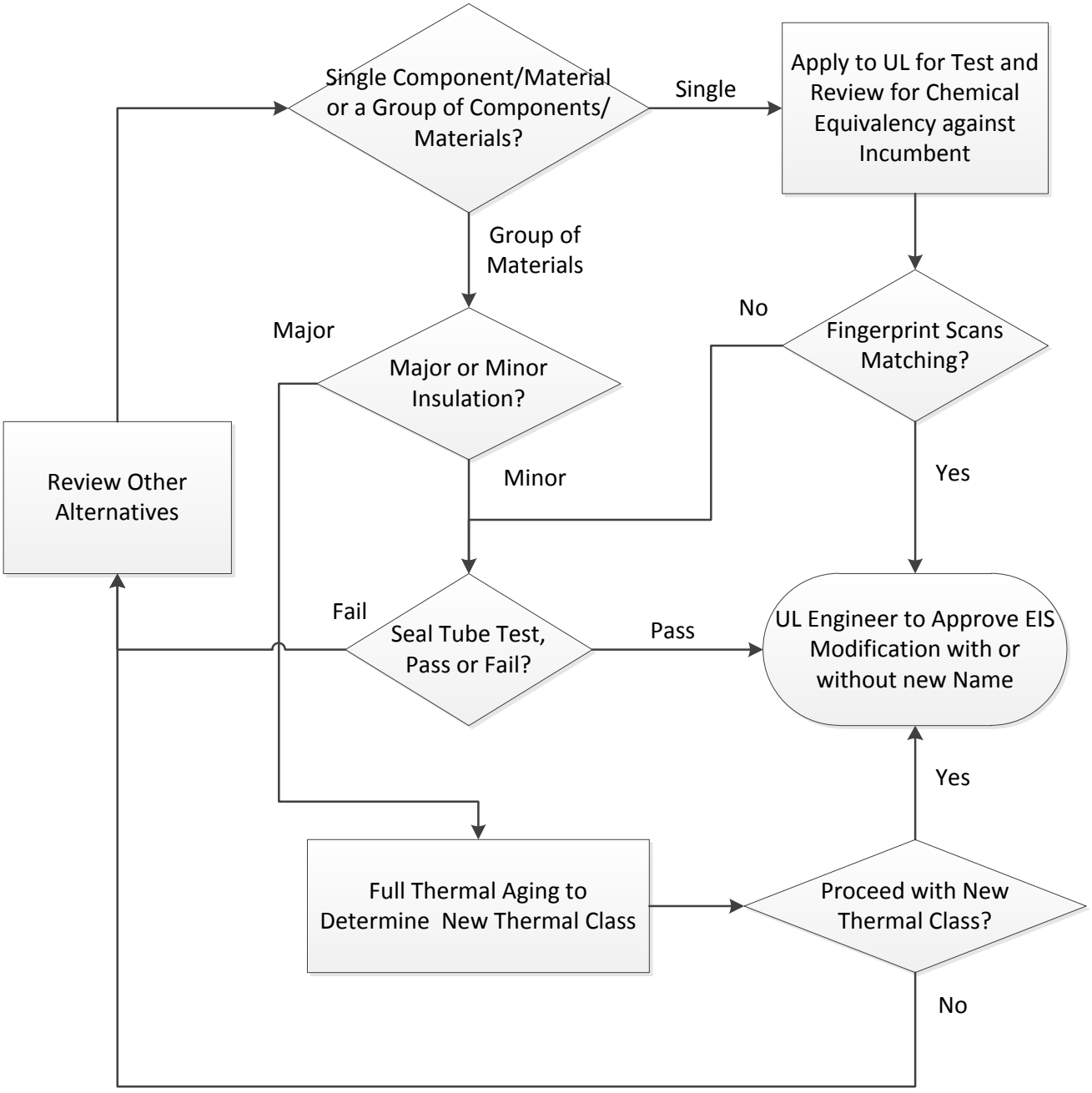
Appendix A

Material Substitution/Addition under UL1446



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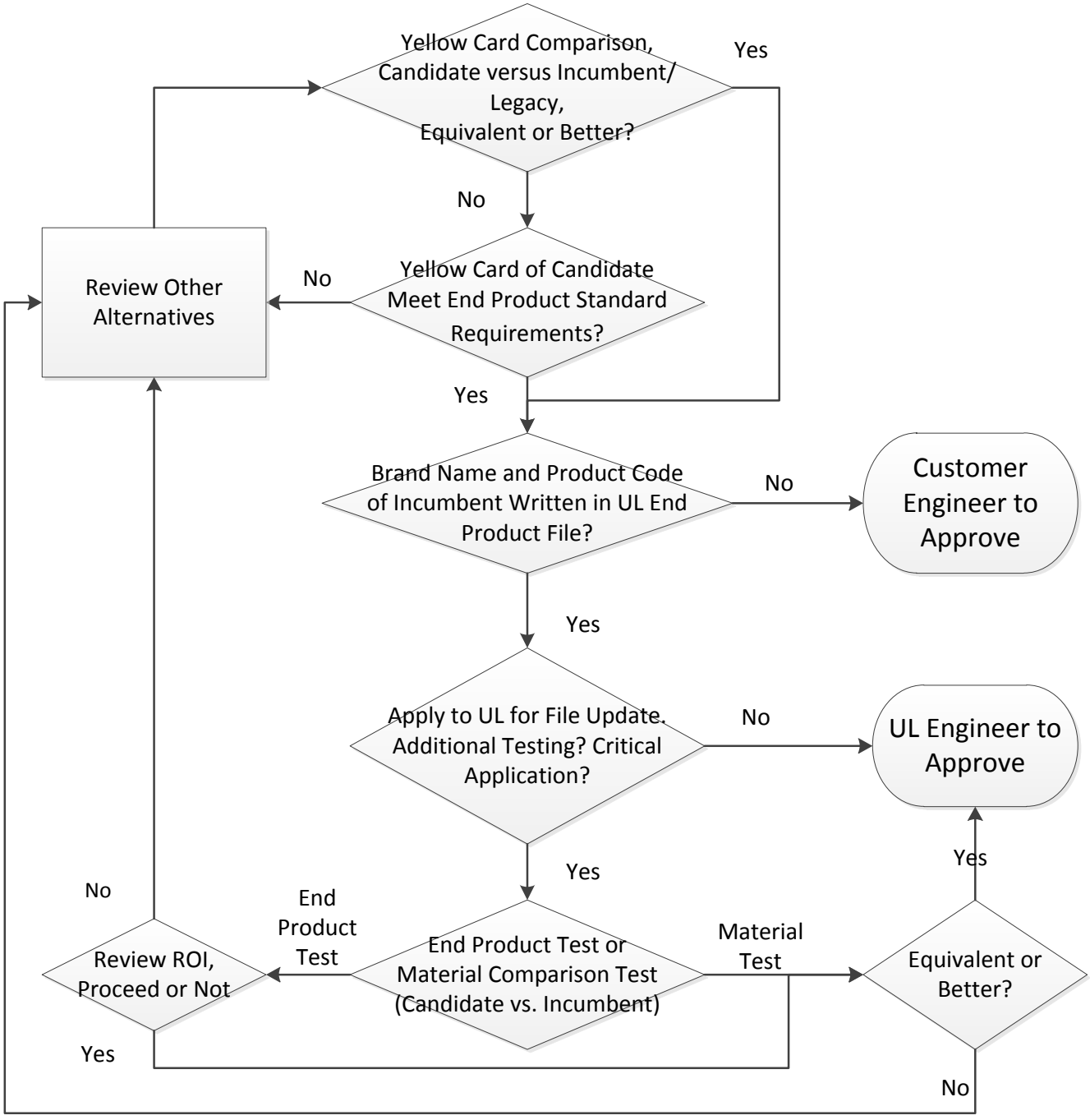
Appendix B

Material Substitution/Addition under UL746C and End Product Standards



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Appendix C

the standard in safety

Underwriters Laboratories

07/16/2008

Mr. Mike Moran
Nohl Electrical Products Corp
5901 W Bender Ct
Milwaukee, WI 53218
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 products itemized below were subjected to infrared analysis with qualitative 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 OBJY2 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, conforming 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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The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

Below is a summary of our results:

NOHL GRADE		REFERENCE GRADE		Conforms/Does Not Conform	Non-Conformance Details
NOHL AP01	N06-01-08	GLASTIC TSF	N06-02-08	Does Not Conform @	The reference dated N06-02-08 shows additional transmittance response @ 1269, 1102, 1015 and 731 cm-1 when compared to the reference dated N06-01-08
NOHL N155	N06-03-08	HAYSITE H755	N06-04-08	Conforms@@	N/A
NOHL N220	N06-05-08	GLASTIC SG-200	N06-06-08	Does Not Conform	The reference dated N06-05-08 exhibits some subtle differences, a small peak @ 1180cm-1 and also @ 827cm-1, when compared to reference dated N06-06-08.
NOHL GP03	N06-07-08	GLASTIC UTR1494	N06-08-08	Does Not Conform@	The reference dated N06-08-08 exhibits some subtle differences, a small peak @ 1409cm-1 and also @ 1099cm-1, when compared to reference dated N06-07-08.
NOHL GP03	N06-07-08	HAYSITE H900	N06-09-08	Does Not Conform	The reference dated dated N06-09-08 exhibits some subtle differences, an additional peak @ 1236cm-1 and a missing peak @ 1255cm-1, when compared to reference dated N06-07-08
NOHL GP03	N06-07-08	HAYSITE H950	N06-10-08	Does Not Conform@	The reference dated N06-10-08 exhibits some subtle differences, additional peaks @ 1236cm-1 and 1093cm-1, when compared to reference dated N06-07-08.

@ - In the comparisons of NOHL AP01 vs GLASTIC TSF, NOHL GP03 vs GLASTIC UTR1494 and NOHL GP03 vs HAYSITE H950, the NOHL 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, the NOHL AP01 grade is eligible to be substituted for GLASTIC TSF grade, NOHL GPO3 grade is eligible to be be substituted for GLASTIC UTR1494 grade and the NOHL GPO3 Grade is eligible to be substituted for HAYSITE H950 as minor components of insulation in a previously evaluated insulation system.

@@ - NOHL N155 grade is eligible to be substituted for HAYSITE H755 grade 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

Bill Buschey
Lead Engineering Associate
Department: 3016CNBK
Tel: 847 664 2874
Fax: 847 313 2874
E-mail: William.A.Buschey@us.ul.com

Reviewed by:

James J. Joyce

James Joyce
Staff Engineer
Department: 3016CNBK
E-mail: james.j.joyce@us.ul.com

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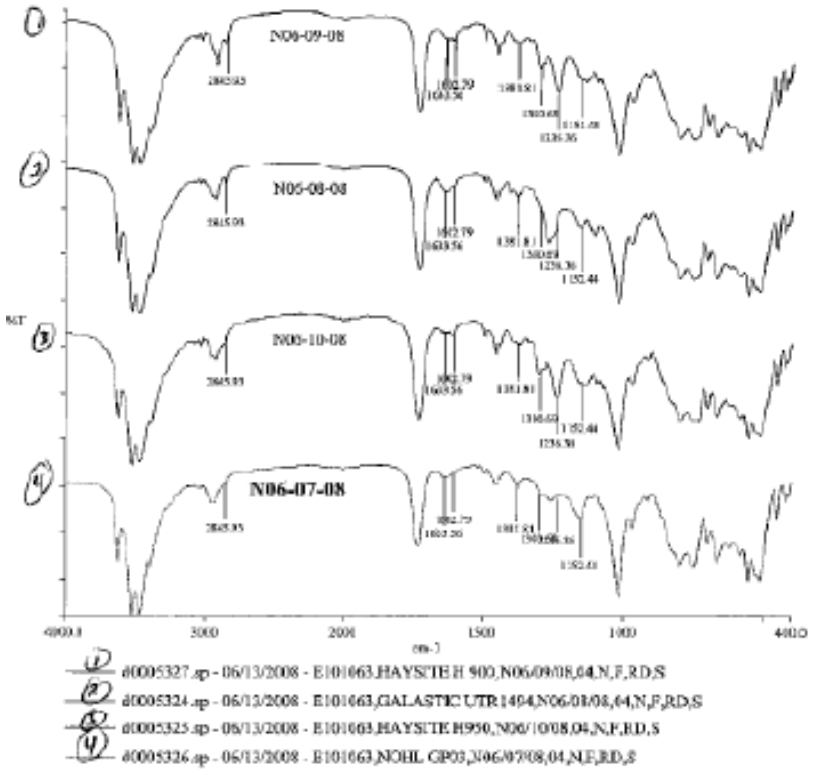

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Appendix D

333 Pfingsten Road
Northbrook, Illinois 60062-2096
United States Country Code (1)
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FAX No. (847) 272-8129
http://www.ul.com

Underwriters Laboratories Inc.®

August 15, 2002

The Gund Co. Inc.
Mr. Stephen P. Gund
2121 Walton Road
St. Louis, MO 63114

Our Reference: E[redacted]

Subject: Addition of PolyPro FR Material to [redacted] UL Files

Dear Mr. Gund:

In response to your request for adding PolyPro FR polypropylene to your customers UL end product files, we have prepared the following guidelines.

Standard Process for Adding New Recognized Component Plastic
Normally when a UL end product manufacturer wants to add a new alternate plastic material to an existing component of the finished product, they would contact the appropriate UL end product engineer who works with their file. If the alternate material is UL Recognized and has equivalent ratings (ie. same or better values) compared to the original material, the end product engineer must then decide if any additional testing is necessary. Guidance is provided by UL Standard 746C or the specific end product standard. If certain end product tests were originally conducted whose result might be affected by a change to this plastic component, then those tests would normally be repeated. As you can see, the tests and related costs would be different for each situation. Once the testing is completed, the new material would be added to the Report and Follow-Up Services Procedure.

Special Process for Adding New Recognized Component Plastic
This type of situation is very unique and would not involve any additional testing. In a situation where it is known that an alternate polymeric material is identical in composition and construction with identical Recognized (QMFZ2) properties to an existing material that has already been fully tested, no end product testing would be required. This direct acceptance applies to the addition of PolyPro FR by The Gund Co., under file E228440, in applications where the Formex material by Illinois Tool Works, under file E121855, has been previously accepted.

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In order for The Gund Company to represent its customers (UL's end product files) for this change, an Agency Authorization form would need to be signed by both companies. Once this is complete, The Gund Company would be able to request UL to add their PolyPro FR to their customer's files. The cost to modify [redacted] files [redacted] and [redacted] would be $3,940, the majority of which includes up front engineering by myself to get the process under way. Once a project is opened, we could use that same project to modify other customers files for an additional cost once we know the number of UL files, Volumes and Reports.

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After your approval of the cost, we would open a new project, prepare the Agency Authorization forms and proceed with the work. Since I am the contact engineer for The Gund Company, all questions relating to this proposal should be directed to myself. Let me know if you have any further questions.

Very Truly Yours,

David S. Sandrof
Sr. Project Engineer
Conformity Assessment Services -3015E
E-mail: David.S.Sandrof@us.ul.com

Reviewed by:

J. R. Thies
Staff Engineer
Conformity Assessment Services -3015E

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Appendix E

2016-03-05

The Gund Co.
5730 W. Douglas Ave
Milwaukee, WI 53218

Attention:
Bob Heppe, R&D Testing Technician/Solomon Chiang Director of Corporate Engineering

Reference: 4787134193
Subject: ASTM D 1822 Tensile Impact

Dear Gentlemen,

Please find attached the test results for Project 4787134193. The "candidate "A"" material performed equal to our better than the "legacy" material with respect to the tensile impact tests conducted. The candidate material is eligible for consideration for material substitution in lieu of certain end product tests for critical applications such as bus bar support (UL 845, Motor Control Centers) -short circuit failure.

Please work with your customers and their respective UL end product Engineers for specific applications that can benefit from these results.

Best Regards,

Ettore Parente
Staff Engineer
UL LLC
Northbrook

TESTS TO BE CONDUCTED:

Test No.	Done	Test Name	[] Comments/Parameters []Tests Conducted by ++
1	2015 /11/ 17	TENSILE IMPACT (TI)	

Tests conducted in accordance with **UL 94 and UL 746A(or)UL746C** that were considered representative of the same tests required by **CSA C22.2 No. 0.17.00** are identified with dual paragraph/clause references in the title of each test on the individual datasheets. Where test names differ or additional test were conducted in accordance with **CSA C22.2 No. 0.17.00**, they are identified by the standard and paragraph/clause information enclosed by parenthesis.

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TEST SAMPLE IDENTIFICATION

The table below is provided to provide correlation of sample numbers to specific product related information. Refer to this table when a test identifies a test sample by "Sample No." only.

Sample Card No.	Date Received	Test No.	Sample No.	Manufacturer, Product Identification and Ratings
2235743	2015/10/27	1	1-3	UTR Length, UTR Width (legacy) GPO3 Length, GPO3 Width (Candidate "A") H950 length and width (Candidate "B")

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Appendix F – UL 67 Summary Data

1) UL End Product Standard Requirements Review –

UL 67 Table 7.1 - Maximum performance level category (PLC) for direct support insulating material.			
	Flammability Rating of Material		
Test Specified	V-0	V-1	V-2
HVTR	1	1	1
CTI	3	3	3
HAI	3	2	2
HWI	4	3	2

UL 67 Table 7.2 - Maximum performance level category (PLC) for indirect support insulating material.				
	Flammability Rating of Material			
Test Specified	V-0	V-1	V-2	HB
HAI	3	2	2	1

UL 67 Table 14.5 - Maximum performance level category (PLC) for barrier used in place of spacing.			
	Flammability Rating of Material		
Test Specified	V-0 or VTM-0	V-1 or VTM-1	V-2 or VTM-2
CTI	3	3	3
HAI	3	2	2
HWI	4	3	2

UL 67 Table 14.6 - Maximum performance level category (PLC) for barrier used in place of spacing in conjuction with minimum air space of 0.013 inch				
	Flammability Rating of Material			
Test Specified	V-0 or VTM-0	V-1 or VTM-1	V-2 or VTM-2	HB
CTI	4	4	4	4
HAI	3	2	2	1
HWI	4	3	2	2

2) Existing vs. Substitute Material Property Evaluation –

Insulating Material for Sole Support of Current-Carry Parts			(Note: Only present day available sheet materials included. Fabricated, not molded sheet materials.)						
a) Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	UL RTI Value	Minimum Thickness	HVTR	CTI	HAI	HWI
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	130C	1/16"	0	0	0	1
NEMA GPO-3	Haysite	GPO-3	H950	160C	1/16"	0	0	0	0
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	130C	1/16"	0	0	0	1
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	130C	1/16"	0	1	0	0
b) Material Options To Add									
NEMA GPO-3	Haysite	GPO-3	H900	130C	1/16"	0	0	0	1
NEMA GPO-3	Nohl	GPO-3	GPO-3	130C	1/16"	0	1	0	1
NEMA GPO-3	Nohl	GPO-3	APO-3	130C	1/16"	0	1	1	2
NEMA GPO-2	Nohl	GPO-2	APO-2	130C	1/16"	0	1	0	2

All Material Options to Add meet standard requirements.

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a) Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	NEMA Standard Flexural Strength (psi)	Grade Data Sheet Flexural Strength (psi)	Grade Data Sheet Compressive Strength (psi)	Grade Data Sheet Tensile Strength (psi)	Grade Data Sheet Impact Strength ft-lb/in
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	18,000	22,100	33,000	7,800	8.9
NEMA GPO-3	Haysite	GPO-3	H950	18,000	25,000			
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	18,000	24,600	39,000	8,900	10
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	18,000	21,000	30,000	10,000	8
b) Material Options To Add								
NEMA GPO-3	Haysite	GPO-3	H900	18,000	18,000	30,000	9,000	8
NEMA GPO-3	Nohl	GPO-3	GPO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-3	Nohl	GPO-3	APO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-2	Nohl	GPO-2	APO-2	18,000	22,000	37,000	9,000	9

All Material Options to Add have equivalent property values.

3) UL 746E & UL 1446 Based Material Equivalency Evaluation –

NEMA Grade	TGC Nohl Grade		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	Glastic UTR	UL 746A Infrared Analysis

Note: Any of the materials and corresponding data can be customized for a specific customer's UL Section General.

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Appendix G – UL 231 Summary Data

1) UL End Product Standard Requirements Review –

UL 231 Table 9.1 - Maximum performance level category (PLC) for insulating material.				
	Flammability Rating of Material			
Test Specified	V-0	V-1	V-2	
CTI	3	3	3	
HAI	3	2	2	
HWI	4	3	2	

UL 231 Table 15.3 - Maximum performance level category (PLC) for barrier used in place of spacing.				
	Flammability Rating of Material			
Test Specified	V-0	V-1	V-2	HB
CTI	4	4	4	4
HAI	3	2	2	1
HWI	4	3	2	2

2) Existing vs. Substitute Material Property Evaluation –

Insulating Material for Sole Support of Current-Carry Parts (Note: Only present day available sheet materials included. Fabricated, not molded sheet materials.)

a) Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	UL RTI Value	Minimum Thickness	HVTR	CTI	HAI	HWI
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	130C	1/16"	0	0	0	1
NEMA GPO-3	Haysite	GPO-3	H950	160C	1/16"	0	0	0	0
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	130C	1/16"	0	0	0	1
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	130C	1/16"	0	1	0	0
NEMA GPO-2	PolyPly	GPO-2	L-40	130C	1/16"	2	0	2	1
b) Material Options To Add									
NEMA GPO-3	Haysite	GPO-3	H900	130C	1/16"	0	0	0	1
NEMA GPO-3	Gund	GPO-3	GPO-3	130C	1/16"	0	0	0	1
NEMA GPO-3	Gund	GPO-3	APO-3	130C	1/16"	0	1	1	2
NEMA GPO-2	Gund	GPO-2	APO-2	130C	1/16"	0	1	0	2

All Material Options to Add meet standard requirements.

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The Process for Adding Equivalent Insulation Materials to UL Recognized Electrical Equipment According To UL 746 – Polymeric Materials: Use In Electrical Equipment Evaluations & UL 1446 – Systems of Insulating Materials

a) Current Material Options	Manufacturer	UL / ANSI Designation	Grade Name	NEMA Standard Flexural Strength (psi)	Grade Data Sheet Flexural Strength (psi)	Grade Data Sheet Compressive Strength (psi)	Grade Data Sheet Tensile Strength (psi)	Grade Data Sheet Impact Strength ft-lb/in
NEMA GPO-3	Glastic	GPO-3	UTR (1494)	18,000	22,100	33,000	7,800	8.9
NEMA GPO-3	Haysite	GPO-3	H950	18,000	25,000			
NEMA GPO-2	Glastic	GPO-2	UTS (1478)	18,000	24,600	39,000	8,900	10
NEMA GPO-2	Haysite	GPO-2	ETS-FR-II	18,000	21,000	30,000	10,000	8
b) Material Options To Add								
NEMA GPO-3	Haysite	GPO-3	H900	18,000	18,000	30,000	9,000	8
NEMA GPO-3	Nohl	GPO-3	GPO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-3	Nohl	GPO-3	APO-3	18,000	22,000	37,000	9,000	9
NEMA GPO-2	Nohl	GPO-2	APO-2	18,000	22,000	37,000	9,000	9

All Material Options to Add have equivalent property values.

3) UL 746E & UL 1446 Based Material Equivalency Evaluation –

NEMA Grade	TGC Nohl Grade		Other Grade	Based on UL Standard
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GPO-3	GPO-3	Equivalent To	Glastic UTR	UL 746A Infrared Analysis

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