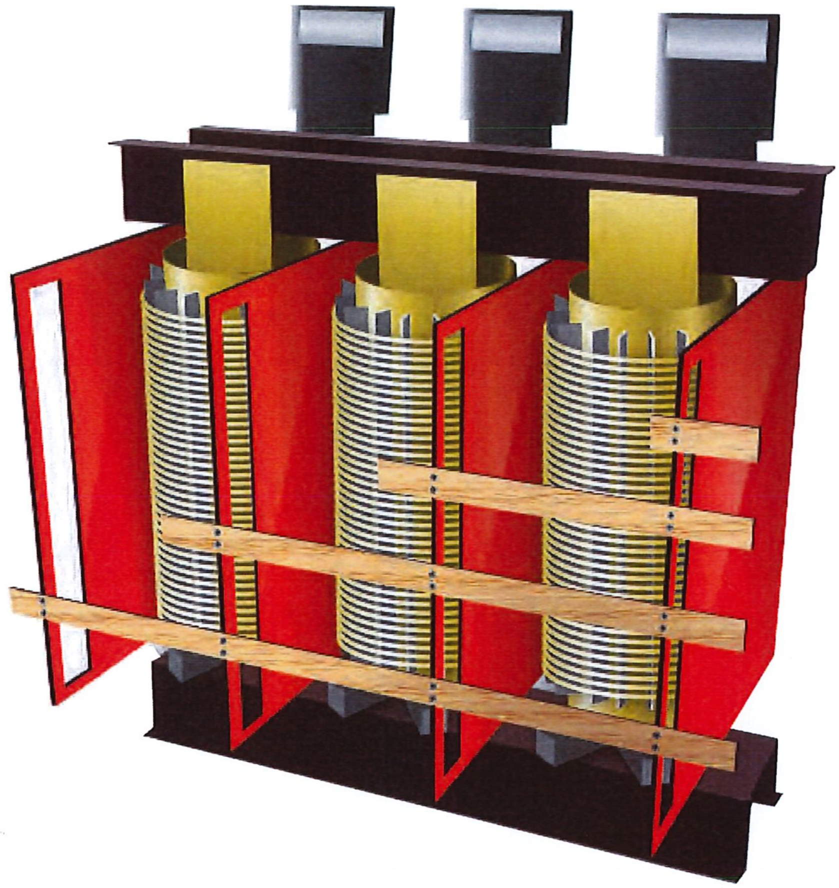
THE GUND COMPANY

MANUFACTURERS & FABRICATORS OF ENGINEERED MATERIAL SOLUTIONS

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

Grade N220

High Temperature 220 °C Laminate



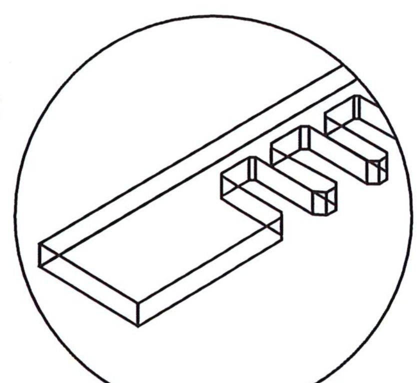
Grade N220 is a high temperature laminate that provides outstanding performance in demanding applications.

- Excellent Mechanical Strength
- Long Term Thermal Stability
- Asbestos Free
- RoHS Compliant
- Exceeds NEMA GPO - 1 Requirements

Typical applications for Grade N220 include winding combs for dry type transformers (pictured right). Other dry type transformer applications including winding bobbins, coil shims, terminal strips, axial spacers, as well as pultruded dogbones, rectangles, and bars.

Grade N220 is also used for high temperature pole collars in DC motors and hydro generators. Grade N220's high temperature characteristics make it an ideal material for use in electric furnaces in the electrometallurgical industry.

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



Custom Fabrication

Regardless of the application, The Gund Company's vertically integrated manufacturing capability and fabrication capacity deliver quality components that meet the exact requirements of our customers.

Availability

Sheets:	.032" (.81mm) to 2.0" (50.80mm) Thickness
Rods:	Dogbones, Rectangles, & Bars Upon Request
Parts:	Fabricated to Match Customer Drawings

<table>
<tr><td>Item:</td><td colspan="4">Class R GPO-1 (N220 from The Gund Company)</td></tr>
<tr><td>Description:</td><td colspan="4">N220 is a specialty grade random glass mat, polyester resin, insulating material for high temperature applications. This material has a relative temperature index of 220 °C (electrical) and 210 °C (mechanical). It has excellent retention of physical and electrical properties at elevated temperatures.</td></tr>
<tr><td>Standards:</td><td colspan="2">NEMA LI-1: GPO-1</td><td colspan="2">IEC 60893: UPGM 201</td></tr>
<tr><td rowspan="4">Availability:</td><td rowspan="3">Laminate Sheets:</td><td></td><td>English Units (in)</td><td>SI Units (mm)</td></tr>
<tr><td>Sheet Size:</td><td>36 x 72
48 x 96</td><td>914 x 1828
1219 x 2438</td></tr>
<tr><td>Thickness:</td><td>0.031 - 2.000
0.118 - 1.500</td><td>0.78 - 50.8
3 - 38.1</td></tr>
<tr><td>Fabricated Parts:</td><td colspan="3">The Gund Company custom fabricates insulation materials to the exact specifications and drawings of our customers.</td></tr>
</table>

Key Characteristics	Test Method	Units - English (SI)	Typical Values
Standard Color	--	--	Natural Beige
Density	--	lbs./in (g/cc)	0.061 (1.7)
Water Absorption (.125")	ASTM D-570	%	0.25
Tensile Strength	ASTM D-638	psi (MPa)	11,000 (76)
Compressive Strength, Flatwise	ASTM D-695	psi (MPa)	32,000 (220)
Flexural Strength, Lengthwise	ASTM D-790	psi (MPa)	21,000 (145)
Bond Strength (.50")	ASTM D-229	lbs. (kg)	1,080 (490)
Shear Strength	ASTM D-732	psi (MPa)	12,000 (83)
IZOD Impact Strength, Edgewise	ASTM D-256	ft.-lbs./in.	11.0
Arc Resistance	ASTM D-495	Seconds	180
Dielectric Strength Perpendicular in Oil (.0625")	ASTM D-149	V/mil (kV/mm)	550 (21.7)
Breakdown Voltage Parallel Pin, in Oil	ASTM D-149	kV	50
Relative Temperature Index	UL746E	°C	220 Electrical 210 Mechanical
UL File Number	--	--	E323105

Item:	Glass Polyester Laminate Sheet Comparative Data for NEMA GPO-1 220 °C Grades
Description:	NEMA GPO-1 Grades are manufactured in various grades to meet the temperature requirements of specific applications. The chart below compares various grades of material rated above 200 °C. Though no NEMA specification exists for high temperature grades in this family, each grade is compared to the NEMA GPO-1 requirements as a baseline.

Key Characteristics	Test Method	Units - English (SI)	NEMA GPO-1 Specification	Grade N220	Grade HST-II	Grade SG-200
Standard Color	--	--	--	Natural Beige	Brown	Natural Beige
Density	--	lbs./in (g/cc)	--	0.061 (1.7)	0.061 (1.7)	0.061 (1.7)
Water Absorption (1/8" thick)	D-570	%	0.70	0.25	0.30	0.30
Tensile Strength	D-638	psi (MPa)	8,000 (55)	12,000 (83)	13,000 (90)	12,500 (86)
Compressive Strength, Flatwise	D-695	psi (MPa)	30,000 (206)	37,000 (255)	33,000 (227)	36,000 (248)
Flexural Strength, Lengthwise	D-790	psi (MPa)	18,000 (124)	24,000 (166)	25,000 (172)	29,000 (199)
Bond Strength (1/2" thick)	D-229	lbs. (kg)	850 (385)	1,080 (490)	1,400 (635)	Not Published
Shear Strength	D-732	psi (MPa)	Not Required	13,000 (90)	14,000 (96)	11,000 (66)
IZOD Impact Strength, Notched	D-256 (method A)	ft.-lbs./in.	8.0	11.0	12.0	12.0
Arc Resistance	D-495	Seconds	100	180	180	120/180 *Post Cured
Dielectric Strength Perpendicular in Oil (1/16")	D-149 (A-short)	V/mil (kV/mm)	300 (11.8)	550 (21.7)	475 (18.7)	625 (24.6)
Breakdown Voltage Parallel Pin, in Oil	D-149 (A-stepped)	kV	40	50	62	50
Relative Temperature Index	UL 746E	°C	NA	220 Electrical 210 Mechanical	220 Electrical 210 Mechanical	210 Electrical 210 Mechanical

Objective:

Compare the physical, electrical, mechanical and thermal endurance properties of N220 from The Gund Company, SG-200 and HST II product.

Executive Summary:

Based on the results of the comparative testing between SG-200, HST II, and N220 from The Gund Company, it can be shown that these products have similar physical, mechanical, electrical, and thermal endurance properties. In some cases, such as dielectric and flex strength thermal endurance, N220 outperforms both SG-220 and HST II. The results show that N220 is a good substitute for applications requiring mechanical strength at elevated temperatures and applications presently using SG-200 or HST II as an insulating material.

Experimental Plan:

The comparison was based on the NEMA standard required testing for GPO- 1 grade material. In addition to the NEMA testing, thermal endurance (flexural and dielectric) testing was performed using ASTM D2304 and UL746E as a guide.

Results: (mean test values reported)

Test	Method	Units	Condition	Nominal Thickness	SG200	HSTII	N220
Dielectric Strength	D149⊥ *Short-oil	V/mil	A	0.062"	569	535	600
Arc Resistance	D149	sec	A	.125"	183.6	142.4	184.3
Flex Strength	D790	ksi	A	0.062"	22.1L/27.6W	22.8L/27.1W	21.8L/26.4W
Izod Impact	D256	ksi	A	0.5"	12*	11.9L/11.4W	11.0L/11.3W
Tensile Strength	D638	ksi	A	0.125"	16.2	12.2	12.4
Comp. Strength	D695	ksi	A	0.5"	37.8	28.3	37.2
Bond Strength	D229	Lbs.	A	0.5"	858	756	1032
Water Absorption	D570	%	D24/23	0.125"	.21	.23	.21

*- From Supplier Datasheet

The graphs on the following pages show the comparative thermal aging curves for SG-200, HST-II, and N220 for the following properties at temperature:

Figure 1- Fluxural Strength Thermal Endurance Comparison at 270 °C
Figure 2- Dielectric Strength Thermal Endurance Comparison at 270 °C
Figure 3- Flexural Strength Thermal Endurance Comparison at 250 °C
Figure 4- Dielectric Strength Thermal Endurance Comparison at 250 °C

Flexural Strength Retention at 270 °C (Figure 1)

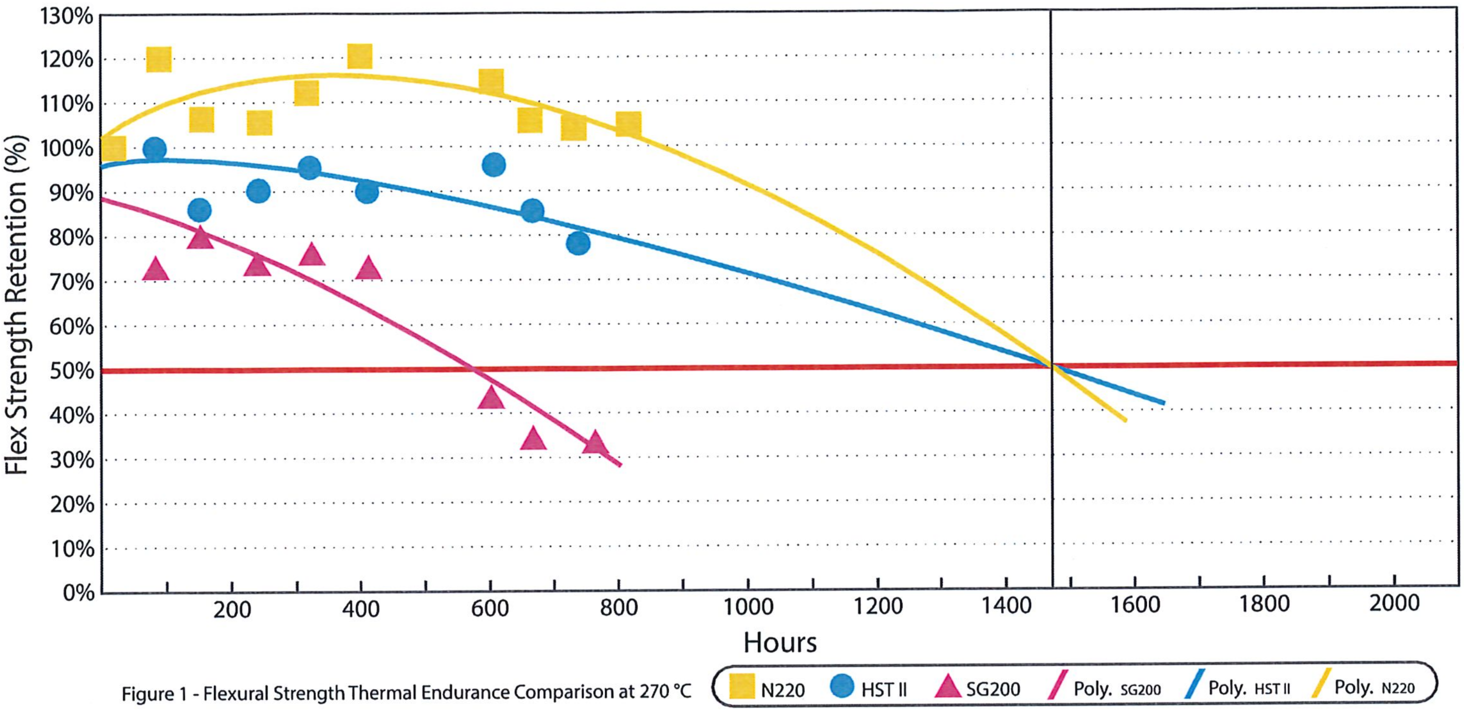


Figure 1 - Flexural Strength Thermal Endurance Comparison at 270 °C

Dielectric Strength Retention at 270 °C (Figure 2)

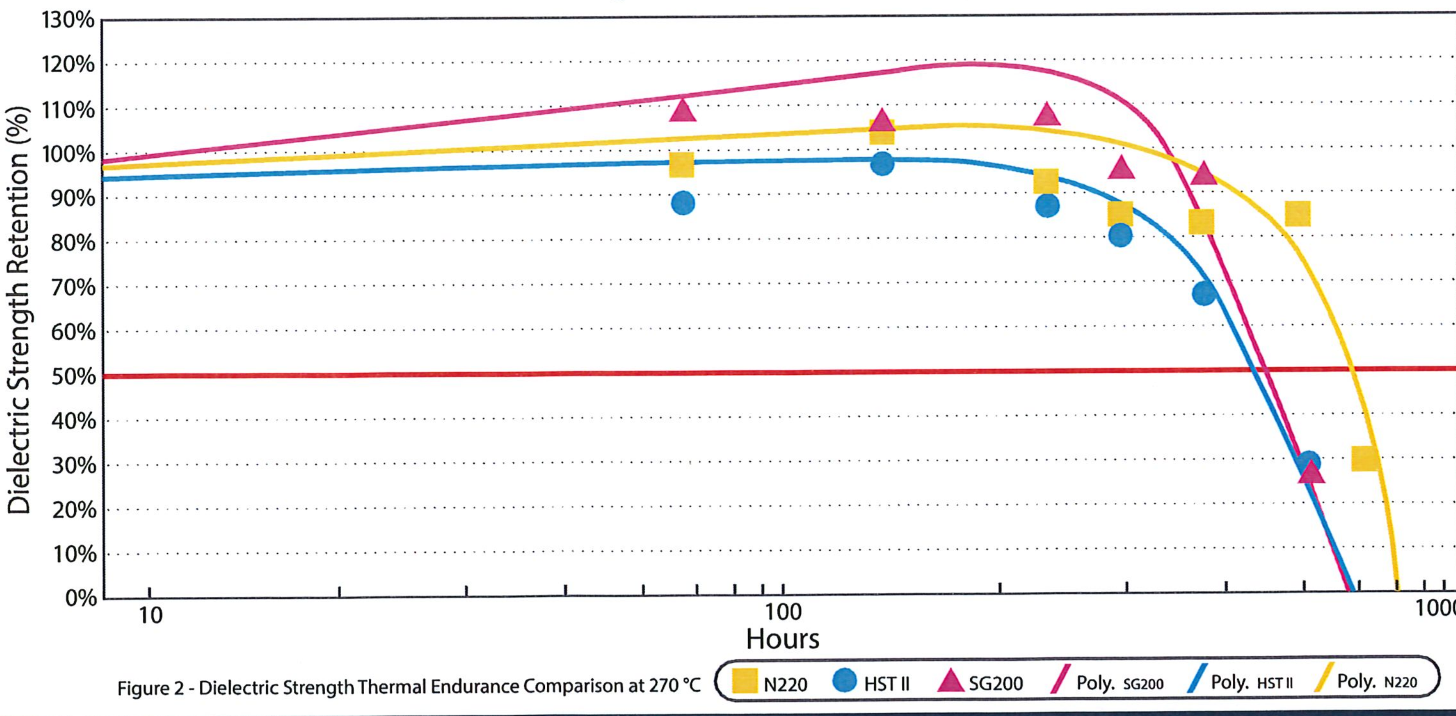


Figure 2 - Dielectric Strength Thermal Endurance Comparison at 270 °C

Flexural Strength Retention at 250 °C (Figure 3)

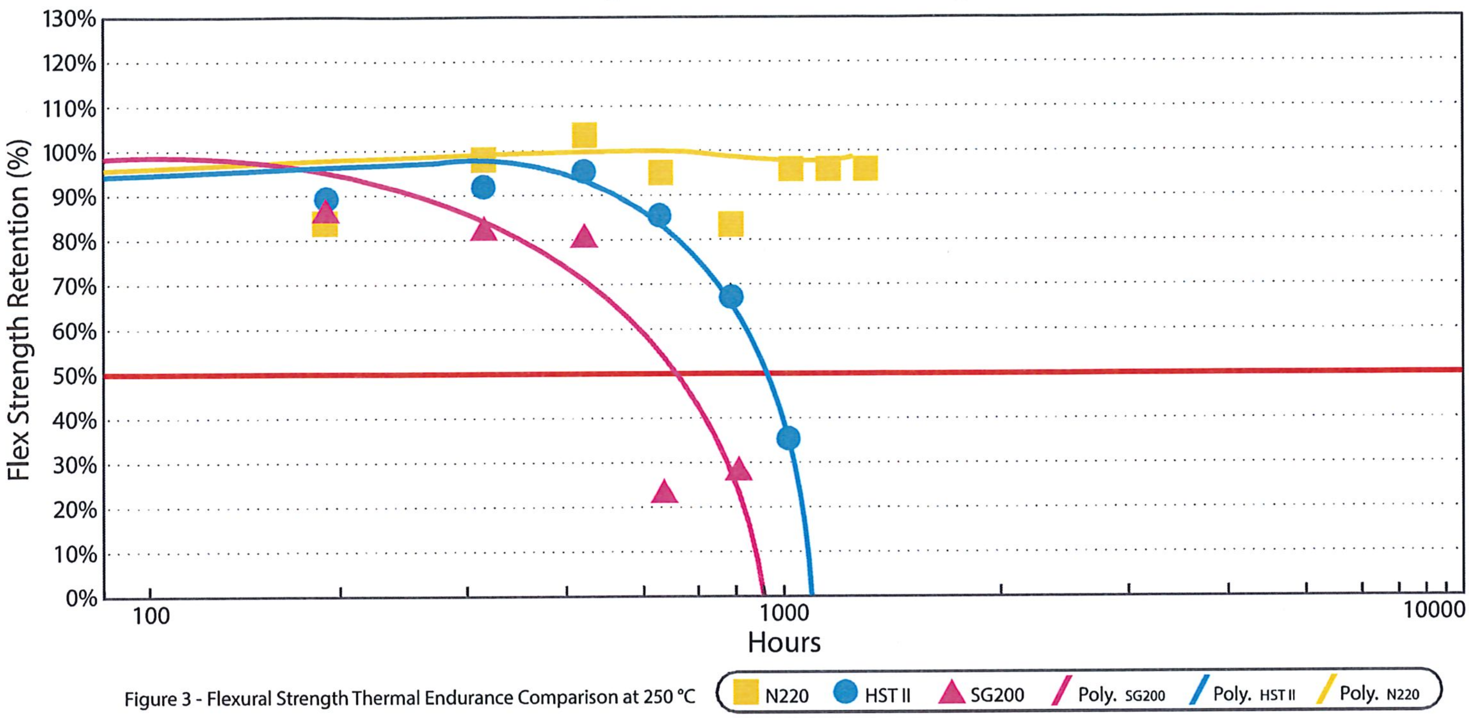


Figure 3 - Flexural Strength Thermal Endurance Comparison at 250 °C

Dielectric Strength Retention at 250 °C (Figure 4)

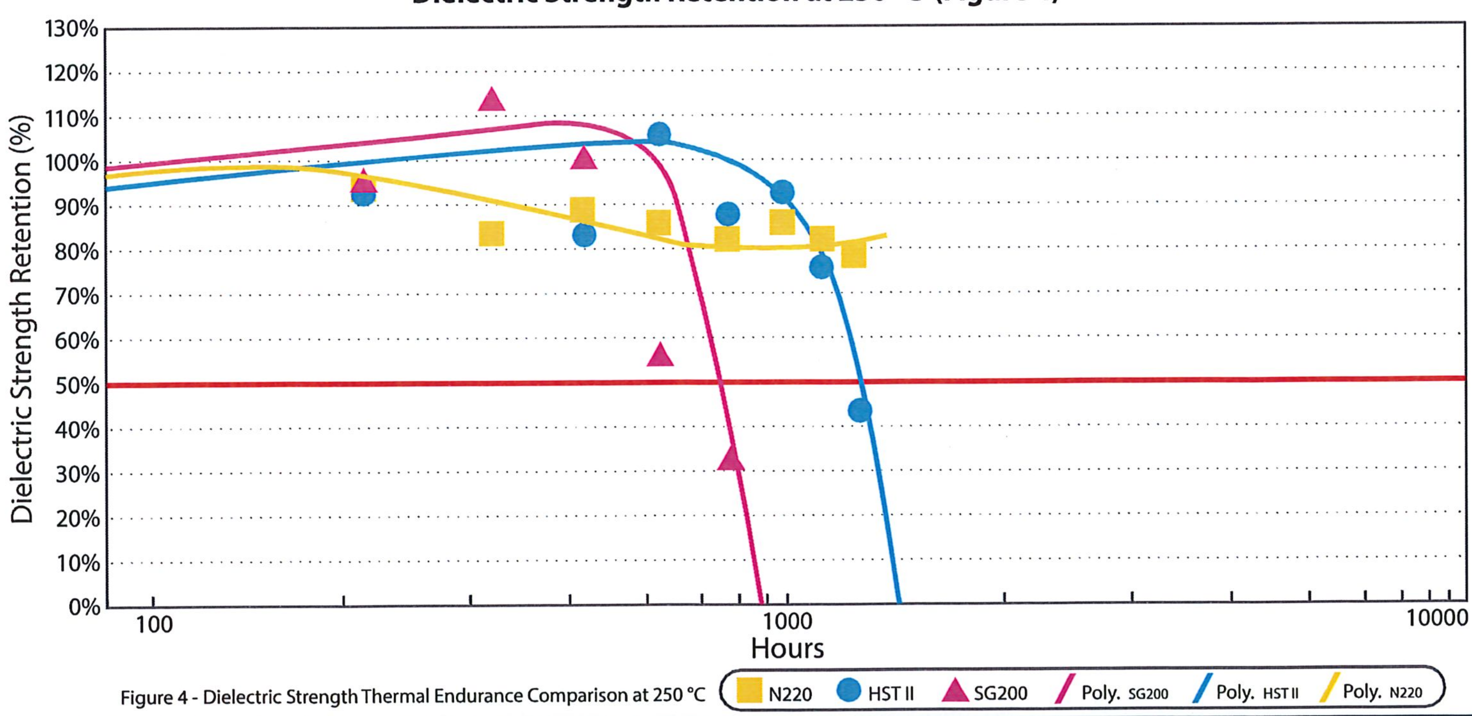


Figure 4 - Dielectric Strength Thermal Endurance Comparison at 250 °C

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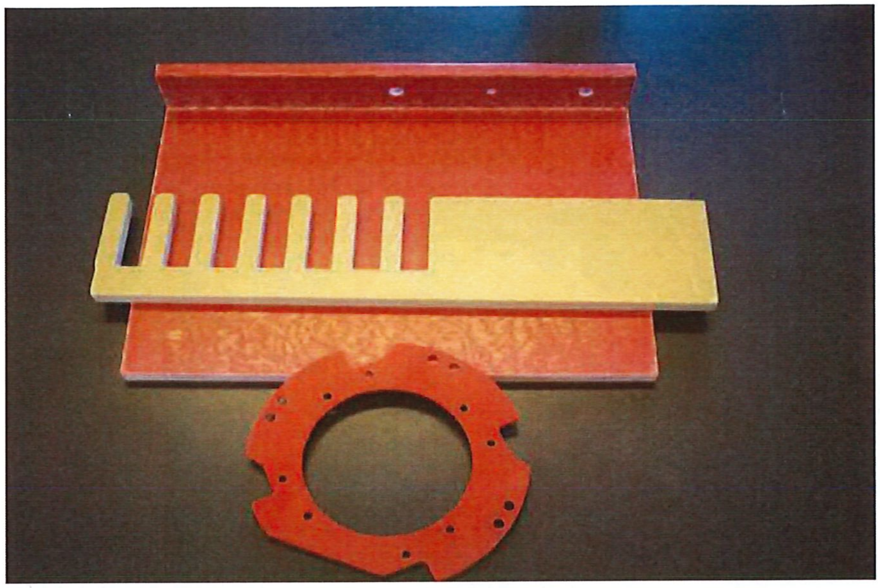


The Gund Company is a manufacturer and fabricator of engineered material solutions. Common applications include custom electrical insulating components for power systems equipment including generators, transformers, switchgear, power supplies, electric motors, and related equipment.

Insulation material selection can be quite a challenge due to the number of factors that influence insulation system engineering and insulation component design. One key criteria for insulation material selection is the material's thermal performance. Since it is impractical to test a material in equipment for as long as it is expected to be in service (20 years), other methods have been developed in order to determine the projected, long- term thermal performance of electrical insulating materials.

The terminology referring to the thermal characteristics for insulation materials can sometimes be confusing because several terms are used interchangeably. The following definitions should help to clarify:

Temperature Classification (IEEE Standard 98-1994)	A term reserved for insulating systems as used in specific equipment, and is no longer recognized as a description of the temperature capability of individual insulating materials (IEEE Standard 98-1994). **Note** — Individual dielectric materials are, however, commonly referred to as Class 90 or Class 105, etc. materials.
Thermal Endurance	Thermal endurance is defined as the relationship between temperature and the amount of time spent at that temperature that would cause electrical insulation to fail under specified conditions of stress, electrical or mechanical- in service or under test.
Relative Temperature Index (RTI)	IEEE Definition — An index that allows relative comparisons of the temperature capability of insulating materials or insulation systems based on specified controlled test conditions (IEEE Standard Dictionary of Electrical and Electronic Terms).

Relative Temperature Index (RTI)	UL Definition — The temperature above which the material is likely to degrade prematurely. This temperature can be determined by performing a thermal aging comparison against a material known to have acceptable performance and known temperature. The RTI can also be simply assigned based on the known performance of the generic class of the material.

The table below shows thermal class designations:

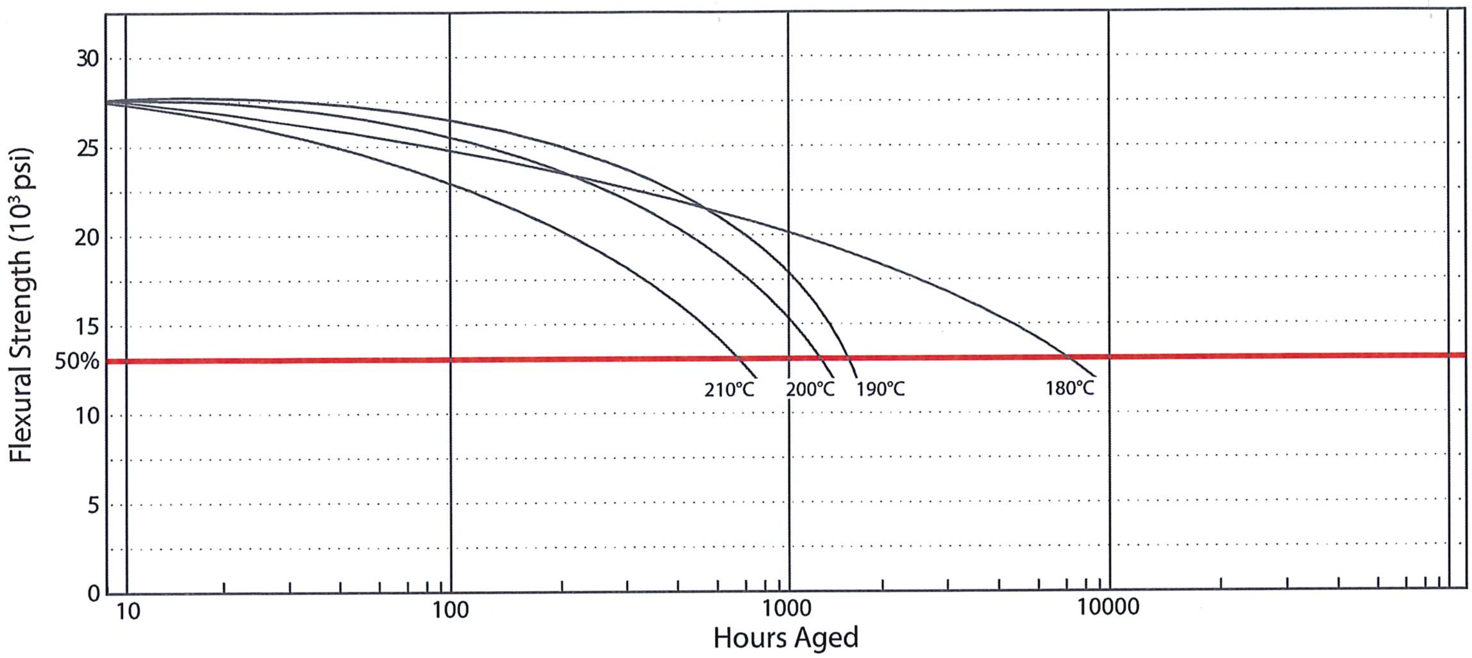
For Thermal Index Values (in °C)	Numerical Designation (Preferred by IEEE)	Letter Designation U.S. (IEC 85)
90.0 up to 104.9	90	None (Y)
105.0 up to 119.9	105	A (A)
120.0 up to 129.9	120	E (E)
130.0 up to 154.9	130	B (B)
155.0 up to 179.9	155	F (F)
180.0 up to 199.9	180	H (H)
200.0 up to 219.9	200	N (200)
220.0 up to 239.9	220	R (220)
90.0 up to 240	240	240 (240)

Today, the relative temperature index is widely accepted by the industry when determining the thermal performance of a material. As seen in the previous definitions, the RTI value can be determined by methods ranging from long-term thermal aging studies to simply assigning values based on the generic class of the material.

The test program for the determination of thermal performance of insulation materials was developed based on the assumption that heat is the chief cause of insulation degradation. Other factors being equal, thermal degradation is accelerated as the temperature is increased and other mechanical and electrical properties deteriorate over time with increasing temperature. According to ASTM D2304, experience has shown that the thermal life is approximately halved for a 10 °C increase in exposure temperature.

Figure 7-1a provides an example of a thermal life curve also known as a "degradation curve".

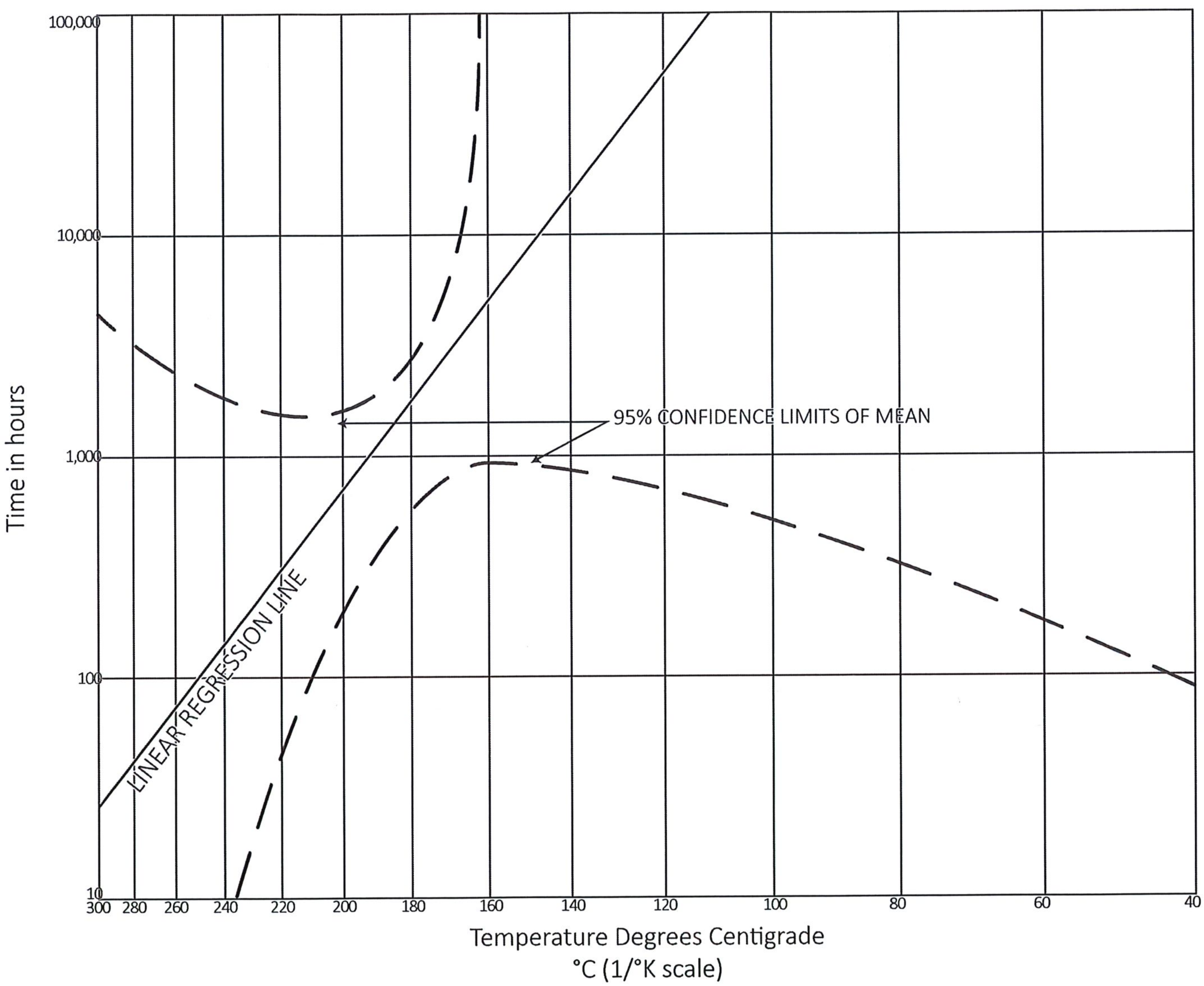
Figure 7-1a Flexural Strength Grade GPO - 2



In order to determine the temperature at which a material will maintain acceptable performance over it's life span, it will be tested at multiple aging temperatures. The thermal life curves generated from these temperatures will be used to plot the Arrhenius Curve. According to W. Tillar Shugg, the author of the Handbook of Electrical and Electronic Insulating Materials: "Tests are conducted at selected elevated temperatures and the time is plotted to the end point criteria on a graph with the logarithm of time as the ordinate and the reciprocal of the absolute temperature, K, as the abscissa (Arrhenius Plot). The graph is then extrapolated, most commonly to 20,000 hours, to determine the temperature index of the material."

An example of an Arrhenius Curve is shown in Example 2.

Example 2 Figure A-40 - Example Arrhenius Curve for Flexural Strength.



A typical long-term aging study would include the following steps:

a) A determination of the electrical and mechanical tests to be performed as part of the testing program.

The electrical RTI is typically based on testing dielectric strength. The mechanical RTI is generally based on testing flexural strength, but may include impact or other mechanical properties depending on the material's use.

b) A determination of the aging temperatures and times for the type of thermal aging study to be completed.

For a full aging study, age must be tested and recorded at a minimum of three and preferably four temperatures. ASTM recommends the lowest temperature test be less than 25 °C above the hottest-spot temperature expected in use so that the thermal life is at least 5,000 hours. Select the highest temperature so that the thermal life is at least 100 hours. If possible, the aging temperature should differ from each other by 20 °C increments, 10 °C increments are also acceptable. Long-term thermal aging is not always necessary in order to assign a thermal index to a material. UL can be generic (UL/ANSI) RTI values to a material if the new material matches favorable to the generic grade. To determine if the new material is a match to the generic grade, UL requires that the materials match the following characteristics:

1. Infrared Analysis
2. Flammability Classification
3. Flexural Strength
4. Ash Content

No thermal aging testing is required when obtaining the generic RTI's by this method. If the new material does not math the UL/ANSI "fingerprint" for the generic material, there are several other methods that can be pursued in order to obtain the RTI values. The decision tree shown in Figure 7.1, illustrates the complexity of the possible scenarios that can occur when trying to obtain RTI values (Reference: UL746E).

Figure 7.1
Testing and evaluation program for rigid industrial laminates

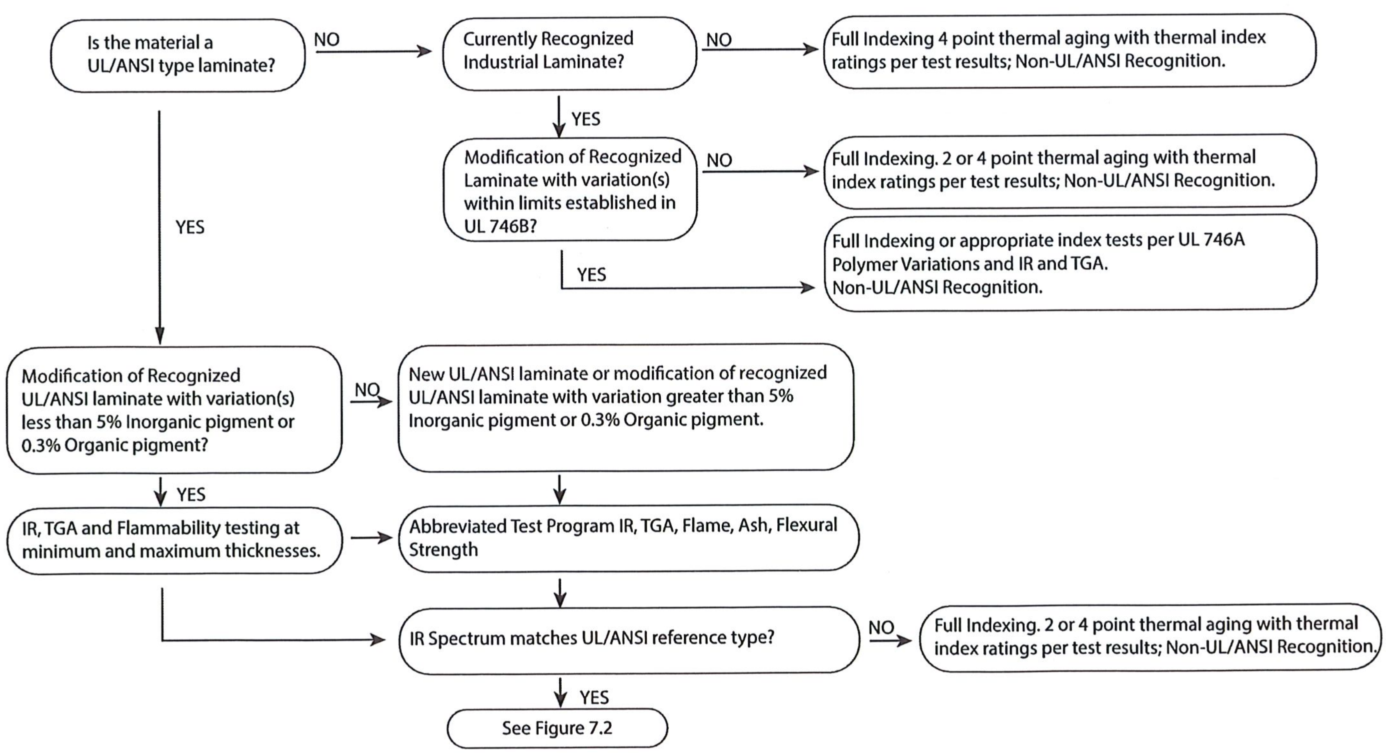
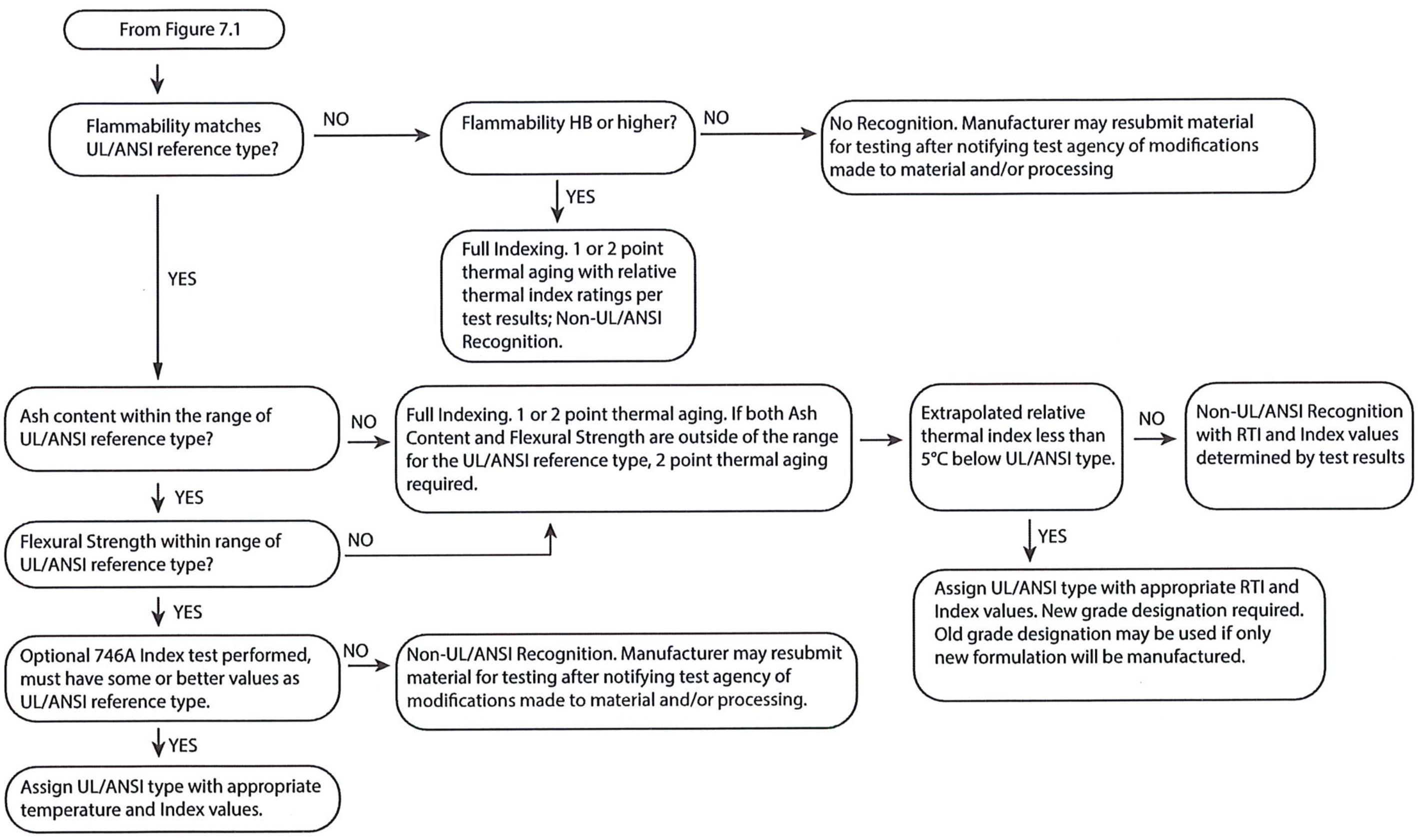


Figure 7.2
Testing and evaluation program for rigid industrial laminates (continued)



Although generic RTI's are useful because they do not require lengthy and costly testing, the RTI values assigned are typically below the values that the material could actually achieve if an aging study were to be performed. For example, the generic RTI values for GPO-3 are 105 °C electrical RTI and 140 °C mechanical RTI. If a single point aging test is performed successfully, the 105 °C electrical RTI can be raised to 120 °C. (Reference UL746E). If a full 4-point aging study were to be performed (duration of 5,000 hours minimum), these values could actually be higher. Hence, with additional testing the RTI values assigned become less and less conservative.

With the variety of methods used to determine the RTI values, it is easy to see how comparing the relative temperature index of two materials may not be an effective way of comparing thermal performance. It is usually not clear if the RTI's assigned were based on the more conservative generally assigned values or if they were based on an aging study.

Thermal Endurance Testing for RTI Per UL746

One sure way to compare materials is to evaluate them side by side for Thermal Endurance. Comparative aging of "like" materials can be done at one temperature; Which, per UL, is typically 50 °C higher than the known or baseline material's UL RTI value.

2. Long Term (UL 746B)
   a) Thermal Aging
      I) One or two temperature point thermal aging of the industrial laminate to 50% retention of initial flexural strength property level. (Dielectric Strength for G-7, GPO-2, and GPO-3 materials). For control purposes, an industrial laminate of the same general UL/ANSI composition having previously been found is to be aged and tested concurrently with the laminate.

Therefore, if a particular type or grade of material has an existing RTI (electrical) of 130 °C, the thermal aging temperature for the comparison test would be 180 °C. Dielectric and/or Flexural Strength testing is conducted periodically over a 21 day period or until the materials have fallen below 50% of their original un-aged test values. The test results are plotted against time in order to generate a thermal life curve. Example 4A provides an illustration of how the thermal life curves can be used to compare the thermal performance of different materials.

Figure 4A - Flex Strength Retention at 210 °C

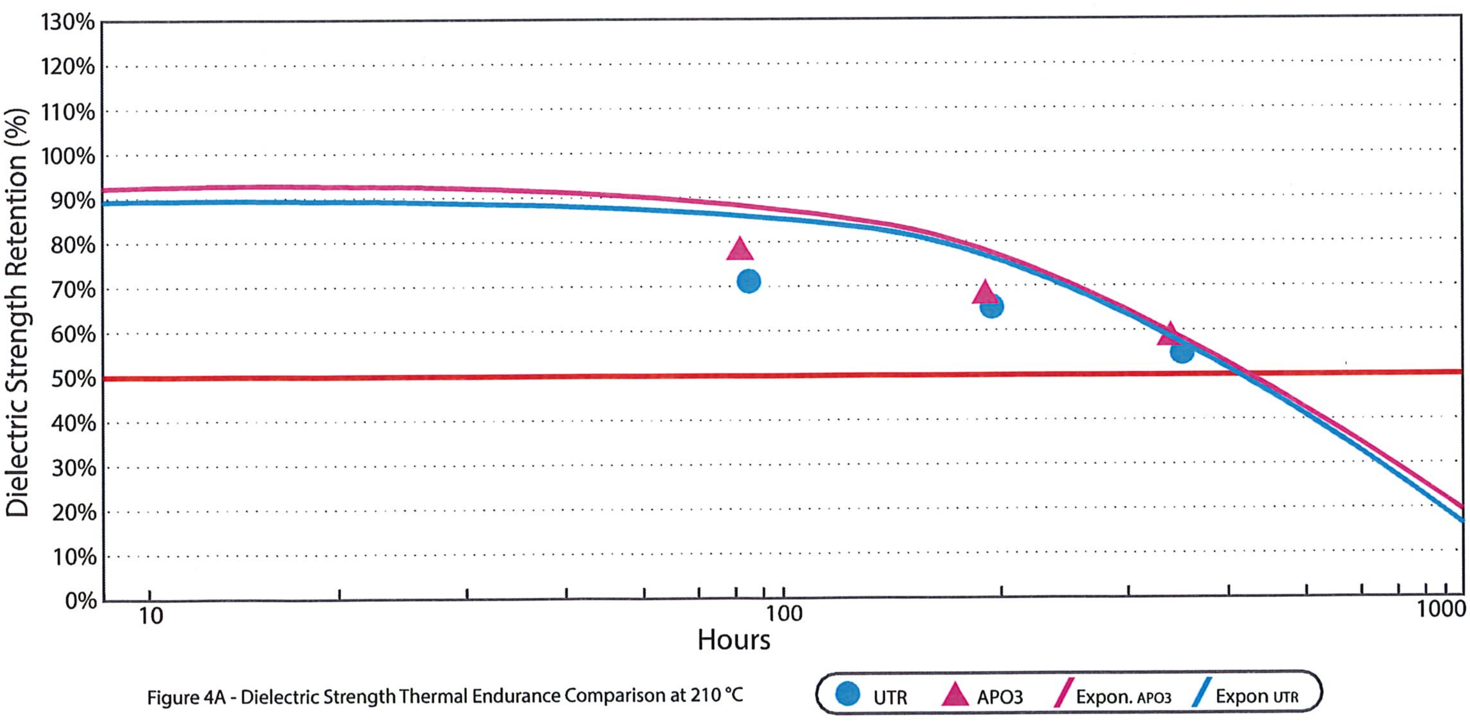


Figure 4A - Dielectric Strength Thermal Endurance Comparison at 210 °C

Certification Testing for RTI of GPO-3 from The Gund Company Per UL746

The Gund Company's material testing laboratory has tested Grade APO-3 (UL File # E75481) for thermal endurance using Grade UTR (UL File #E81928) as a control. Because the materials are both UL/ANSI GPO-3 grades, it can be tested for a 130 °C electrical RTI and a 160 °C mechanical RTI using the Grade UTR as a control. The electrical RTI testing is done based on testing dielectric strength at 180 °C (50 °C over the control RTI) concurrently for both materials. The mechanical RTI testing is done based on testing flexural strength at 210 °C (50 °C over the control RTI).

The results of the mechanical RTI testing are indicated in Figure 4A (p. 13). Based on these results, The Gund Company certifies that Grade APO-3 meets the UL746 requirements for an RTI mechanical rating of 160 °C.

The Gund Company's material testing laboratory can provide thermal performance testing for comparative analysis. Whether for product development, material selection, or material performance comparison, The Gund Company can provide a clearer picture of a material's performance. In addition to thermal endurance testing we also have the capability to do several other physical, mechanical, and electrical tests. Let us help you simplify your material selection process.

Dedicated inventory, complete fabrication facilities, and extremely short lead-times insures The Gund Company's ability to provide electrical insulating materials for the manufacture, and repair of electrical power systems equipment. The Gund Company is up to the challenge to engineer lower cost alternatives.

Contact us today to learn more about material testing.

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