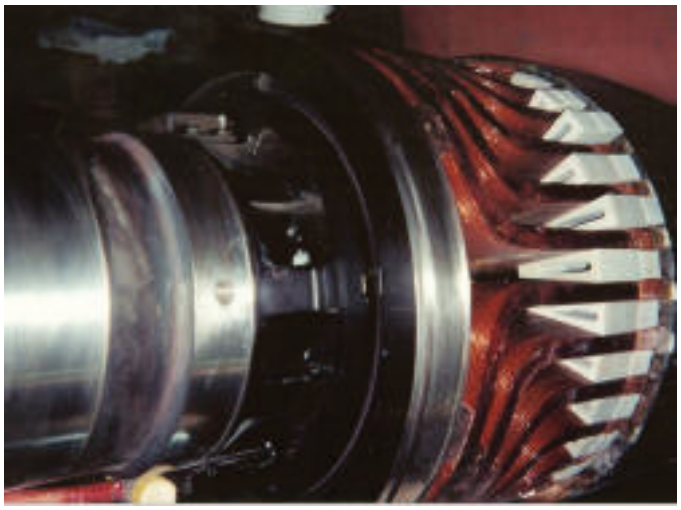
Generator Repair Topics

Brominated Insulation Materials



The Gund Company fabricates custom insulation components for the manufacture and repair of power generation equipment.

Recently, a large OEM sent out a technical information letter indicating the problems associated with the use of brominated insulation materials in generator field applications such as retaining ring insulation and end coil blocking.

The OEM technical information letter indicated the following regarding retaining ring insulation specifically:

> *Recent retaining ring inspections performed during routine generator maintenance have identified cases of surface pitting and degradation on a few 18-18 nonmagnetic retaining rings. Material analysis has shown that the insulation from the affected rings contained fire retardant chemicals, which can cause surface pitting and degradation.*

The Gund Company supplies formed retaining ring insulation using a Class F, non-brominated glass epoxy material that meets OEM requirements for non-brominated materials. The OEM letter corresponds closely with the information presented to the EPRI Working Group Meeting in 1997 presented below.

Though we cannot control utility or repair company specifications, we have long encouraged and provided nonbrominated material options for all rotating equipment applications. Ultimately, our customers are responsible for their designs and specifications. Whenever possible, The Gund Company attempts to share information and offer options for our customer's consideration. In addition, our laboratory offers specific testing capability for all NEMA and a wide range of related UL and ANSI testing requirements.

It should be noted that The Gund Company has been aware of the potential issues involved with the use of brominated insulation materials for years. In fact, we published a technical newsletter on the topic several years ago indicating a specific problem related to out gassing involving the use of brominated G-10/FR4 materials in stator wedge applications. We have included that stator wedge case study below. We are also including excerpts below from the EPRI paper on brominated materials.

ERPI Study on Brominated Insulation Materials

In 1997, an ERPI Working Group Meeting presented a paper on the topic of brominated insulation materials such as NEMA G-10/FR4 (technically NEMA FR4) and NEMA FR5 glass epoxy laminates. The NEMA Standard LI-1 establishes the specifications for "Industrial Thermosetting Products" and classifies glass epoxy laminates as follows:

Material	Description	Temperature Class
NEMA G-10	Glass Epoxy Laminate- Not Flame Retardant	130C- Class B
NEMA G-11	Glass Epoxy Laminate- Not Flame Retardant	155C- Class F
NEMA FR4	Glass Epoxy Laminate- Flame Retardant	130C- Class B
NEMA FR5	Glass Epoxy Laminate- Flame Retardant	155C- Class F

Note:

1) Temperature Class based on typically UL RTI (Relative Temperature Index- electrical & mechanical) values for these grades. It should be noted that NEMA standards to not require a minimum RTI value. It should also be noted that some manufacturers make grades with higher than typical RTI values. For instance, typical NEMA G-11 is rated at 155C, but Grade G-11 from The Gund Company is rated at 180C.
2) Flammability based on UL 94 Standard- Flame Retardant based on UL 94.

Glass epoxy laminates are commonly used in generator applications as stator slot wedges, filler strip, end winding blocking. These materials are also commonly used in rotor field applications for coil blocking, creepage blocking, sub-slot filler, and retaining ring insulation.

» "The FR grades were developed for the printed circuit board industry which was using G-10 but wanted the fire retardant property. It is possible, that when G-10 was specified, a substitution to an FR-4 grade was made in the interest of a lower price. One supplier lists G-10 and FR-4 as completely interchangeable."
» "An MSDS for FR-4 states that 'burning liberates CO, CO2, BR2, and smoke' and 'may give off toxic hydrogen bromide gas'." Whether FR4 or FR5, the impact would be the same.
» "Bromine is a halogen (Periodic Table Group Classification 17) with a chemical behavior much like chlorine, although not as reactive as chlorine and fluorine. The halogens are strongly electronegative while metals are electropositive; thus, they react with each other."
» "Halogens have played a role in stress corrosion cracking on the 18Mn-5Cr retaining rings and more recently on 18Mn-18Cr retaining rings on at least three units. Bromine, along with chlorine and sulphur, were the contaminants identified with the 18Mn-18Cr retaining ring SCC on the 750MW rotor in Porto Tolle, Italy (1995). In 1996, chlorine was also found in SCCs on the 18Mn-18Cr rings of some 800MW water cooled rotors in Perm, Russia. ABB in Richmond, VA found SCC on two 18Mn-18Cr retaining rings, chlorine is suspected (1997)."
» "In the fall (of 1997), one major OEM has made the decision to use only "non-brominated" materials for synchronous generator applications. They are confident that only G-11 has been used for retaining ring insulation, but FR-4 has been used for stator wedges in the past. Another large repair facility used FR for stator wedges but was not pleased with the machining (delamination) and stopped using FR grades."

Though a full EPRI study was never commissioned on the topic of brominated insulation materials used in large rotating equipment, anecdotal evidence and laboratory testing shows that brominated materials out gas causing dimensional stability issues and potential metal corrosion issues.

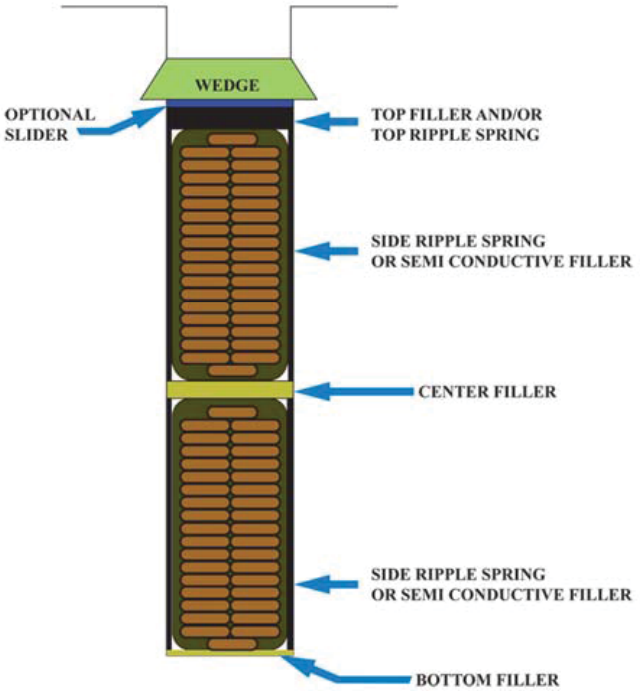
Over the years, The Gund Company has observed, tested, and shared our experience related to the problems caused by brominated materials with the industry. For years, it has been our recommendation to avoid the use of all materials in the G-10 / FR4 family in favor of NEMA G-11 material. It is a fact that the worldwide production of NEMA G-10 material has diminished drastically in favor of NEMA FR4 materials that meet the same specification but add flame retardancy. Many manufacturers importing their raw material b-stage or even finished sheet material as well as many distributors and fabricators of these materials have little knowledge of the potential problems caused by the use of brominated materials in rotating equipment so they freely substitute FR4 material when G-10 is specified. This practice has been so common in the industry for the last 20 years that there is no practical way to avoid it other than moving all specifications to NEMA G-11 material. With improved temperature resistance, NEMA G-11 offers a cost effective solution.

Though The Gund Company does not perform repair services, our company has considerable experience with generator insulation systems based on the insulation kits we supply for generator rewinds and rewedges and the information shared with us by utilities.

In our experience, a good generator rewedge or rewind should last at least 10 to 15 years. Unfortunately, we receive feedback from our utility customers that regularly indicate that less than "best practice" materials and techniques were used on their generator repair project resulting in repairs that last only three to seven years.

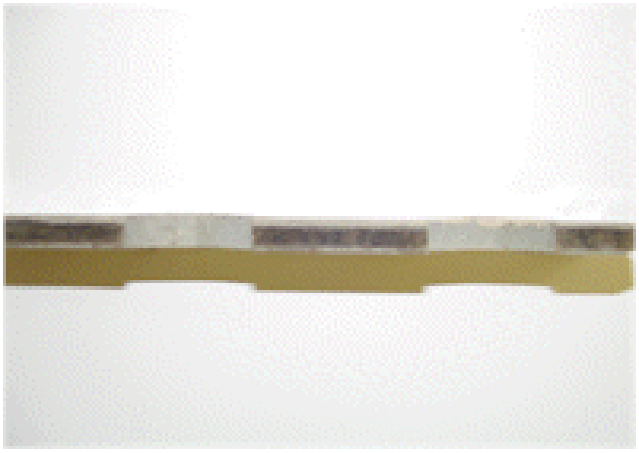
Of course, there are many variables that determine the life of a rewedge including the type of start/stop operational duties, oil in the machine, the condition of the bars and their end winding support system among various other issues. That being said, many generators inspected for wedge tightness show the results of poor material selection or inferior wedge system design.

STATOR SLOT DIAGRAM



Case Study

A customer recently shared information about a recent rewedge. The previous rewedge had lasted only seven years. A wedge system's performance is dependent upon material selection, wedge and insulation system design, and proper installation techniques.



In this unit, a primary problem with the wedge system was the use of NEMA G10/FR4 glass epoxy material. This material is a high pressure rigid laminate manufactured from bi-directional glass cloth with a flame retardant, 130C rated epoxy resin system. This material is a standard grade of insulation material that is readily available at a low cost.

OEM:	General Electric- Lynn Unit- 1962
Stator Data:	60 Slots 0.875” Slot Width 156” Slot Length Estimated 36” Core I.D.
Problem: Loose Wedges	1) Brominated NEMA G-10/FR4 material used for wedges 2) Wedges also had no end wedge locking system in the design. 3) Numerous gaps were left in the slot without wedges
Solution: Rewedge	1) Replaced wedges using Low Shrink Black Canvas (Grade LSBC). 2) Redesigned wedge system to include top ripple spring. 3) Redesigned insulation system to include semi-conductive side filler for partial discharge dissipation.

Unfortunately, the flame retardant used in the resin system is a bromine based additive that outgasses at elevated temperature resulting in the loss of dimensional stability (i.e. shrinkage). Shrinking wedges result in loose wedges. The G10/FR4 flat wedge at left shows the results of out gassing and shrinkage allowing it to be deformed by the top ripple spring.

Anecdotal field evidence and dimensional stability testing have indicated that Low Shrink Black Canvas is a higher performance grade for wedge applications.

Many repair companies do not have the experience to recognize poor performing wedge system designs so they either try to replace the existing design in kind or they install the only wedge system that they may know from their limited experience. It is important to review a machine's current wedge system to identify the best option for optimal long term performance.

Often, utilities fail to specify the wedge materials and designs used in their generator repair. By sharing information from our experience, we hope to help the industry make informed decisions when specifying their generator repair projects.

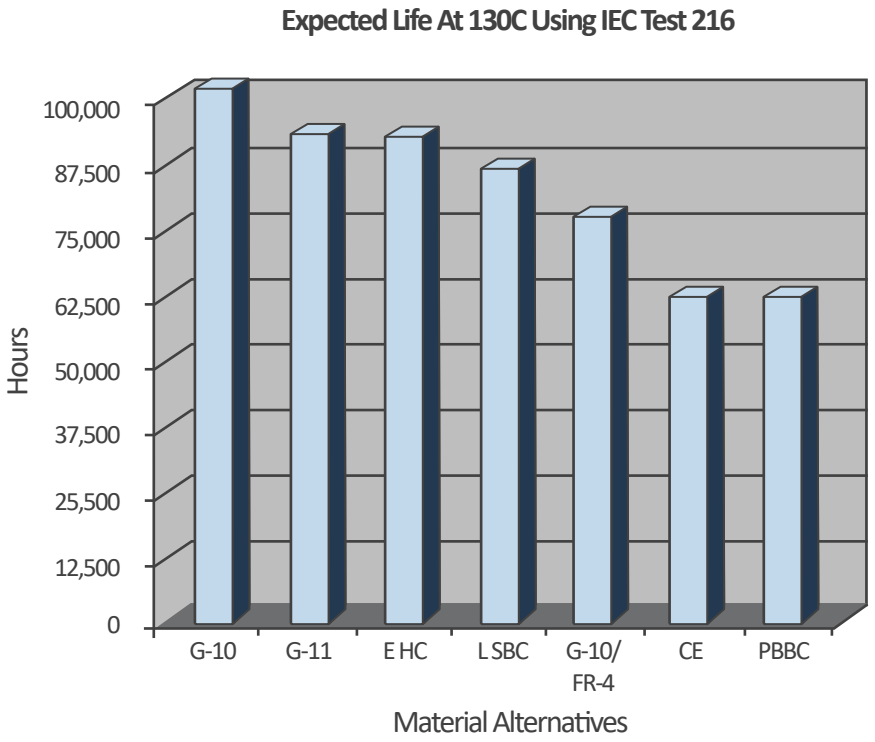
The Gund Company believes that material selection is critically important to the life cycle performance of a generator rewedge. The Gund Company has engaged an independent laboratory to test several common wedge materials to measure their performance. This testing along with our decades of experience with generator rewedge operations has allowed us to make many observations about material performance.

The chart below at right indicates that materials will shrink at different rates at elevated temperature. The results at right show the dimensional stability of a material under no mechanical load at 130C. Even without the mechanical loading, some materials showed significant shrinkage at a relatively low number of hours at elevated temperature.

Based on this testing, it was possible to gain an additional insight that the standard material data sheets did not illuminate. In addition, our years of experience confirm the testing results. Machines with glass polyester, G-10/ FR4, standard canvas phenolic, or even Post Bake Black Canvas perform relatively poorly.

Of course, the wedge system design and installation can be just as important as material selection in the performance of the rewedge over its life cycle.

Note the performance of the NEMA G-10 material. Due to industry practices regarding the substitution of the prevalent G10/FR4 material even when NEMA G-10 is specified, it is recommend to use NEMA G-11 material to avoid any potential supply of brominated NEMA G-10/FR4 material.



For each material is estimated. End of life, for test purposes, was set at 5% loss of material mass to simulate shrinkage.

All of the information, suggestions, and recommendations pertaining to the properties and uses of the products herein are based upon tests and data believed to be accurate; however, the final determination regarding the suitability of any material described herein for the use contemplated, the manner of such use, and whether the use infringes any patents is the sole responsibility of the user. The Gund Company does not design or engineer insulation components. There is no warranty, expressed or implied, including, without limitation warranty of merchantability or fitness for a particular purpose. Under no circumstances shall we be liable for incidental or consequential loss or damage.

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