NANOMATERIALS IN LIQUID INSULATION TO IMPROVE MOISTURE RESISTANCE AND PULSE ENDURANCE IN INVERTER DUTY MOTOR APPLICATIONS

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Abstract: Nanomaterials are becoming widely used in many commercial and consumer applications. Previous reports have documented results when used in magnet wire enamels as well as secondary impregnating resins in the electrical insulation industry. Additional work has shown opportunities to develop synergies between these two insulation layers to improve moisture resistance and pulse endurance survivability over current state of the art systems that use micron-size inorganic materials.

Key words: wire enamels, impregnating resins, unsaturated polyesters, corona, pulse endurance, inverter duty, moisture resistance, nanomaterials

I. INTRODUCTION

Previous reports have been presented [1,2] that outlined the impact of nanomaterials on primary and secondary liquid electrical insulation coatings. New methods to control the operation of motors are being developed as the desire for increased efficiency continues to be a value driver for this industry. These drive controllers are often just called inverters or inverter drives and provide a fast and accurate method of controlling the operation of an electric motor. However, the use of inverter drives results in unique electrical stresses of the insulation materials as illustrated in Figure 1 below. These stresses have been attributed to causing premature failure of the electrical insulation in motors.

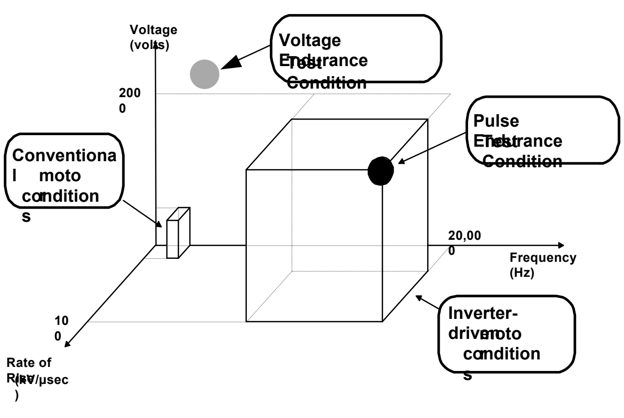

Figure 1. Insulation Stresses

As the demands for motor and transformer efficiency increase the use of nanomaterials could play an important role in meeting these requirements. The benefits of this technology can be tailored based on the features of the nanomaterials itself and are applicable in the primary and secondary insulation chemistries used in the industry.

II. MOISTURE CONDITIONS

A. Test Methodology

The test method was previously developed by GE and Phelps Dodge to test insulation systems under stresses of temperature, humidity and voltage. Bifilar twisted wire pairs were made to do the testing as illustrated in Figure 2

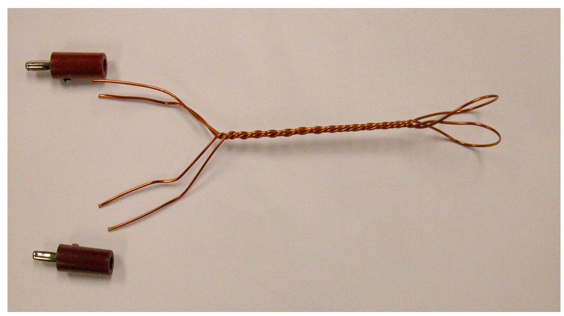

Figure 2 – Bifilar twisted wire

The test apparatus as shown below in Figure 3

Figure 3 – Moisture Test Apparatus

The wire pairs were run to failure under the following conditions:

Temperature: Water bath at 80°C
Voltage: 1500 volts

Failure is defined as a leakage current of 15 mA.

B. Results

Experiments have been designed in multiple phases to optimize the system and determine any positive synergistic impact on moisture test results using various coating combinations. These experiments have included current "state of the art" systems to compare to the nanomaterial-modified products.

No adjustments to viscosity were made so the products were used "as supplied" leading to a variation in cured film thickness. These variations were normalized by dividing the minutes to failure by the measured thickness as coated on a Q panel leading to a "minutes/mil" value. Table I below summarizes the results of Phase I of the program.

Product	Thickness (mils)	Time to Failure (minutes)	"Minutes/mil"
Waterborne A	0.2	20	100
Waterborne B	0.3	34	113
Polyester A	1	60	60
Polyester B	0.7	251	358
Polyester C	1.16	77	66
Polyester D	1.24	97	78
Polyester E	1.28	548	428
Polyester F	0.71	163	230
Alkyd	1.1	125	114
Epoxy A	0.2	37	185
Epoxy B	21.6	5887	273
Polybutadiene	0.96	149	155
MW 35 A	N/A	3	3
MW 35 B	N/A	15	15

Table I – Bifilar Test Results

From these results, Polyester B, Polyester E and Epoxy B have been designated for further study using various wire constructions. It should be noted that higher film build does lead to a longer time to failure but the true efficiency per mil of film build is indicated by the "minutes/mil" value.

Each layer was cured ensuring a smooth, continuous film before the next layer was applied. Squares were then cut from the cured panel and placed in the test instrument as shown in Figure 5 below. Polyester E, which contains nanomaterials, is shown as the highest "minutes/mil" to failure sample. Further optimization using base resin modifications is being done on this sample based on results from our Pulse Endurance work discussed in the next sections.

III. PULSE ENDURANCE

A. Test Methodology

Work was initially done using twisted wire pairs of MW 35 construction but there was concern about reproducibility due to low build and the small sample size possibly leading to poor coating.
Our new method involves coating aluminum panels using a drawdown rod as shown in Figure 4 below.

Figure 4 – Aluminum Panel with Drawdown Rod

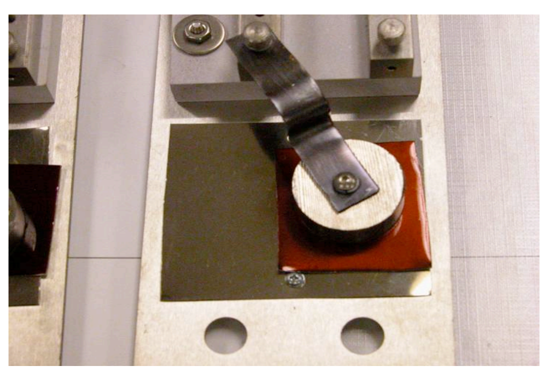

Figure 5 – Pulse Endurance Test Fixture

Test conditions used were:

Voltage:	+/- 1500 volts AC
Frequency:	20,000 Hz
Pulse Width:	24E-6 seconds
Temperature	180°C

B. Results

Samples of various chemistries were made and applied to test substrates, individually and in combination, as primary and secondary insulation layers.

Studies have been done to measure the effect on pulse endurance testing when combining nano-modified primary and secondary insulation coatings as an insulation system.

The samples in Chart 1 below are as follows:

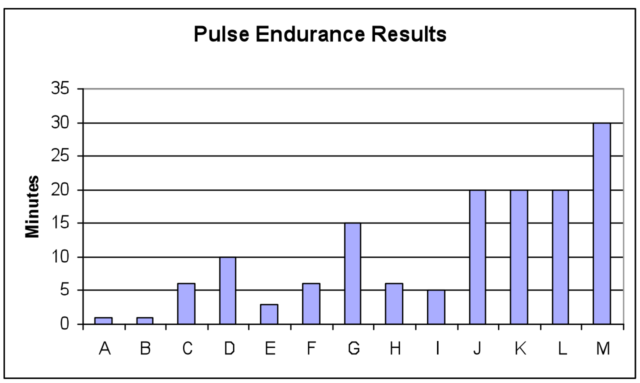

Chart I. Pulse Endurance

IV, CONCLUSIONS

A. Moisture Resistance

MW 35 wire with no secondary coating was the quickest failure in the test.

Waterborne secondary coatings were the quickest failures of all the experiments with secondary coatings.

Nanomaterial-modified unsaturated polyester had the best result in this test.

B. Pulse Endurance

Single insulation layer samples had the quickest failures.

Nanomaterial modification of the primary insulation layer had a greater impact than nanomaterial modification of the secondary layer using this test protocol.

Use of nanomaterials in both insulation layers showed a 33% increase in survivability vs samples with nanomaterials in only one layer.

Use of primary and secondary materials that were modified at the base resin level and with nanomaterials showed a 50% increase over the samples with no base resin modification.

REFERENCES

[1] *The Future of Nanomaterial Coatings in Electrical Insulation Materials,* Mark Winkeler and Ronald Goetter, , Proceedings: The Electrical Manufacturing and Coil Winding Conference, 2008.

[2]. *Nanomaterials in Liquid Insulation Materials for Use in Inverter Duty Applications* Mark Winkeler and Ronald Goetter,

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