

## Determination of the Insulation Classification of Some Nigerian Paper Products

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**Abstract:** Empirical studies have shown that over 30% of electrical machine failures result from insulation failure. The temperature-rise, which electrical machines may safely withstand is determined by the limiting temperature of the insulating material used in them. This study presents, the experimental results of a research to qualify some paper insulating materials thermally by determining their insulation class. Ten sample varieties of Nigerian paper products were experimented with to determine their insulation classification. The samples were cut into definite dimensions and weighed. Each paper product was made into two samples, one sample was left in its ordinary state while, the other sample was impregnated with insulating varnish. Both samples were subjected to a heat run in a sealed industrial oven, while, measuring the insulation resistance of the given sample at regular temperature intervals, until the sample burns out. The measured values of weight, insulation resistance and temperature are shown in tables. Curves were plotted to show the variation of insulation resistance with temperature. From the experiments, seven of the paper products require impregnation to be suitable for class Y insulation, whose maximum permissible temperature is 90°C. The other three paper products are unsuitable for class Y insulation even when impregnated.

**Key words:** Paper products, limiting temperature, insulation class, samples, impregnation, resistance

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### INTRODUCTION

Insulating materials are essentially non-metals and have a great variety of constituents: they may be organic or inorganic, vegetal, mineral or animal in origin, uniform or heterogeneous in texture, natural or artificial. A good insulating material would have high dielectric strength, particularly at high temperatures, good heat conductivity, good mechanical properties and be non-hygroscopic (Chen and Davies, 2000; Dissado, 2002; Berleze and Robert, 2003; Heylen and Postoyalko, 2003; Lewis, 2003). The behavior of insulating materials under different thermal and environmental conditions is an important subject of investigation. For example, David *et al.* (2007) used a DC ramp test to examine the dielectric response of a stator winding insulation, while, Ohki and Hirai (2007) examined the electrical conduction and breakdown properties of several biodegradable polymers. It is also, important to determine the flashover and insulation breakdown levels of insulating materials. Peng *et al.* (2007), Wieck *et al.* (2007) and Jianlin *et al.* (2007) are examined the flashover performance of HVDC insulator strings, breakers and transmission lines under iced conditions. Excessive temperatures can cause complete failure of insulation due to melting, softening or burning, resulting in machine failure. Empirical studies have shown that over 30% of electrical machine failures result from

insulation failure (Wiedenbrug, 2003). Hudon *et al.* (2000), Mayoux (2000), Nelson *et al.* (2000), Oraee (2000) and Crine (2005) are examined the degradation of insulating materials under electrical stress and the problem of aging and life expectancy of motor insulation. It is therefore, important to qualify insulating materials thermally and to improve their thermal capabilities.

Insulating materials are classified thermally as Y, A, E, B, F, H and C. The allowable temperature for each of these classes is defined in NEMA, BSI and IEC standards. The maximum permissible temperatures for these classes are, respectively 90, 105, 120, 130, 155, 180 and >180°C. The figures are based on a 20 years working life under average conditions. The IEEE and IEC have developed practices and procedures for the thermal evaluation of insulation systems for electrical machines. In their research, Paraskevas *et al.* (2006), Fu *et al.* (2007), Kikuchi *et al.* (2008), Rui-Jin *et al.* (2008) and Ishikawa *et al.* (2009) are investigated the influence of ambient and operating temperatures on the dielectric properties and aging of insulating materials, while, the influence of water absorption on the dielectric quality of insulators was studied by Kyritsis (2000) and Hong *et al.* (2009a, b). High quality insulating materials are expensive and for many developing nations, they are imported. This experimental study is an effort to thermally qualify and lassify paper products available in Nigeria. By measuring their maximum

operating temperature, their insulation class can be determined, thus, helping to determine their level of use as insulating materials for electrical machines and if they can serve as viable alternative insulating materials to imported ones. Conducting the experimentation with both impregnated and unimpregnated samples will help to evaluate the improvement in insulation resistance resulting from impregnation. Ten sample varieties of paper products were used in the experimental research.

## MATERIALS AND METHODS

The paper products used in the experiments were;

- Carton paper
- Newsprint
- Emboss wood
- Chiboard
- Manila paper
- Glossy paper
- Eighty gram paper
- Sixty gram paper
- Strawboard
- Emboss card

**Preparation of the paper samples:** Each paper sample measured 10×5 cm. The thickness of each type of paper was maintained as manufactured in order not to alter the

integrity of the paper material. Each of the 10 paper materials was made into two samples, with one sample impregnated and the other unimpregnated. The sample to be impregnated was immersed in hot insulating varnish for 10 h and then dried slowly for 2 days. The weight of the samples before impregnation, immediately after impregnation and after drying as well as the initial insulation resistances (at room temperature) of both samples of each paper material are shown in Table 1.

**Heat run:** The two samples of each of the ten paper materials were subjected to a heat-run in a well-lagged industrial oven shown in Fig. 1. The insulation resistances of the samples were measured at regular temperature intervals of 20°C, until the given sample burns out. Table 2 shows the insulation resistance measurement of the paper materials during the heat-run.



Fig. 1: The inner chambers of the oven

Table 1: Initial parameters of the paper samples

Paper samples	Weight of samples (g)			Insulation resistances (MO)	
	Before varnishing	Immediately after varnishing	After drying	Impregnated	Unimpregnated
Carton	5.426	9.005	8.805	200	100
Newsprint	0.240	0.605	0.514	200	200
Emboss wood	1.311	2.005	1.868	200	200
Chiboard	1.236	1.492	1.400	200	200
Manila	1.148	1.386	1.321	200	200
Glossy paper	0.894	1.002	0.999	200	150
80 g	0.401	0.521	0.492	200	200
60 g	0.295	0.355	0.300	200	200
Strawboard	4.458	4.999	4.799	200	200
Emboss card	1.013	1.650	1.590	200	200

Table 2: Heat run and insulation resistance measurement of wood samples

Paper materials	30°C		50°C		70°C		90°C		110°C	
	V (MO)	nV (MO)	V (MO)	nV (MO)	V (MO)	nV (MO)	V (MO)	nV (MO)	V (MO)	nV (MO)
Carton	150	50	100	20	40	10	8.5	3	-	-
Newsprint	150	75	75	30	20	12	4	1.8	-	-
Emboss wood	150	75	100	30	50	10	8.5	4	-	-
Chiboard	150	75	100	20	40	10	8.5	4.5	-	-
Manila	150	75	100	40	50	20	8	2	-	-
Glossy paper	150	50	100	20	40	9	8	1.5	-	-
80 g	150	75	75	40	40	10	4	0.8	-	-
60 g	150	75	75	30	30	10	4	0.8	-	-
Strawboard	150	75	100	40	30	20	8	1.4	-	-
Emboss card	150	75	100	40	50	20	8	1.6	-	-

V = varnished, nV = non-varnished

## RESULTS AND DISCUSSION

From Table 2, it is clearly shown that all the paper products were burnt at 110°C, whether impregnated or not. Seven impregnated samples of the paper products (carton paper, emboss wood, chiboard, manila paper, gloss paper, strawboard and emboss card) had insulation resistances up to 8 MΩ at 90°C, which is the limiting temperature for class Y insulation. Thus, they are suitable for class Y insulation when impregnated. The other three impregnated paper products (newsprint, 80 and 60 g paper) had insulation resistance of 4 MΩ at 90°C and so are unsuitable for class Y insulation even when impregnated. All the ten unimpregnated samples of the paper products had insulation resistances below 5 MΩ at 90°C. It implies that none of the paper products can be used for class Y insulation without impregnation.

## CONCLUSION

The results of the research show that all the ten paper products used in the experimentation cannot be used for even class Y insulation without impregnation. However, seven of the paper products (carton paper, emboss wood, chiboard, manila paper, gloss paper, strawboard and emboss card) are suitable for class Y insulation when impregnated. The other three paper products (newsprint, 80 and 60 g paper) are unsuitable for class Y insulation whether impregnated or not.

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