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# 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 paper 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 90ºC. The other three paper products are unsuitable for class Y insulation even when impregnated.

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

## 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 David, 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 and his colleagues used a D.C. ramp test to examine the dielectric response of a stator winding insulation, while Ohki and Hirai examined the electrical conduction and breakdown properties of several biodegradable polymers (David *et al.*, 2007; Ohki and Hirai, 2007). It is also important to determine the flashover and insulation breakdown levels of insulating materials. Peng, Wieck and Janlin examined the flashover performance of HVDC insulator strings, breakers and transmission lines under iced conditions (Peng, *et al.*, 2007; Wieck, *et al.*, 2007; Janlin *et al.*, 2007). 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). Mayoux, Oraee, Nelson, Hudon and Crine examined the degradation of insulating materials under electrical stress and the problem of aging and life expectancy of motor insulation (Hudon *et al.*, 2000; Mayoux, 2000; Nelson *et al*, 2000; Oraee, 2000; Crine, 2005). 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 90ºC, 105ºC, 120ºC, 130ºC, 155ºC, 180ºC and > 180ºC. The figures are based on a 20–year 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 work, Paraskevas, Fu, Kikuchi, Rui-Jin and Ishikawa investigated the influence of ambient and operating temperatures on the dielectric properties and aging of insulating materials (Paraskevas, *et al*, 2006; Fu *et al*, 2007; Kikuchi *et al*, 2008; Rui-Jin *et al*, 2008; Ishikawa *et al*, 2009), while the influence of water absorption on the dielectric quality of insulators was studied by Kyritsis and Hong (Kyritsis *et al.*, 2005; Hong *et al.*, 2009; Hong *et al.*, 2009). High quality insulating materials are expensive and for many developing nations, they are imported. This experimental study is an effort to thermally qualify and classify 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 work.

## MATERIALS AND METHODS

**The paper products used in the experiments were:**

- Carton paper
- Newsprint
- Emboss wood
- Chipboard
- Manila paper
- Glossy paper
- 80 gram paper
- 60 gram paper
- Strawboard
- Emboss card.

**Preparation of the Paper Samples:** Each paper sample measured 10cm x 5cm . 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 ten 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 ten hours and then dried slowly for two days. The weight of the samples before impregnation, immediately after impregnation, and after drying as well as the initial insulation resistance (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 resistance of the samples were measured at regular temperature intervals of 20ºC until the given sample burns out. Table 2 shows the insulation resistance measurement of the paper materials during the heat- run.

## RESULTS AND DISCUSSION

Fig. 2 (a, b, c and d) are curves of the insulation resistance versus temperature for the impregnated samples of the ten paper products. From Table 2, it is clearly seen that all the paper products were burnt at 110ºC, whether impregnated or not. Seven impregnated samples of the paper products (Carton paper, Emboss wood, Chipboard, Manila paper, Gloss paper, Strawboard, and Emboss card) had insulation resistance up to 8MΩ at 90 ºC, 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 gram paper and 60 gram paper) had insulation resistance of 4MΩ at 90ºC and so are unsuitable for class Y insulation even when impregnated. All the ten unimpregnated samples of the paper products had insulation resistance below 5MΩ at 90 ºC. It implies that none of the paper products can be used for class Y insulation without impregnation.

Fig 1: The Inner chambers of the oven

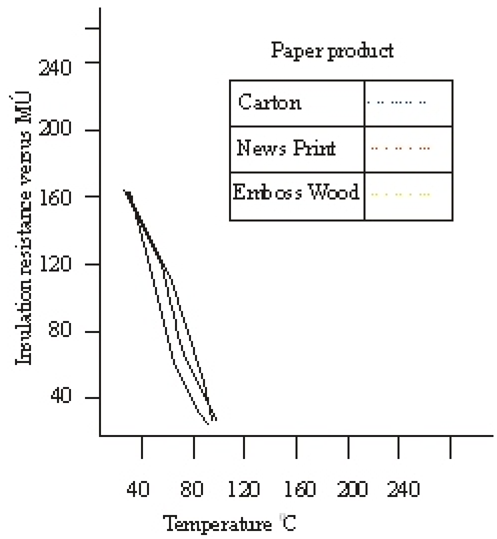


Fig 2a: Insulation resistance versus temperature

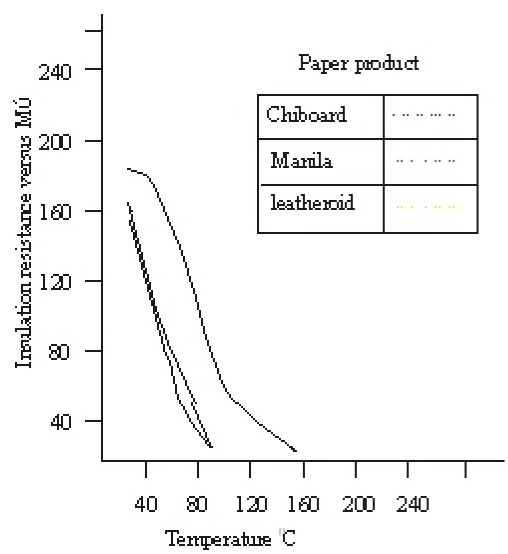


Fig 2b: Insulation resistance versus temperature

Table 1: Initial Parameters of the Paper Samples

| Paper Samples | Weight of Samples (g) Before Varnishing | Immediately after Varnishing | After drying | Insulation Resistance (MΩ) 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 |
| Gloss paper | 0.894 | 1.002 | 0.999 | 200 | 150 |
| 80 grams | 0.401 | 0.521 | 0.492 | 200 | 200 |
| 60 grams | 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 (V= varnished nV= non- varnished)

| | 30ºC | | 50ºC | | 70ºC | | 90ºC | | 110ºC | |
|---|---|---|---|---|---|---|---|---|---|---|
| Paper Materials | V MΩ | nV MΩ | V MΩ | nV MΩ | V MΩ | nV MΩ | V MΩ | nV MΩ | V MΩ | nV MΩ |
| 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 | | |
| Gloss paper | 150 | 50 | 100 | 20 | 40 | 9 | 8 | 1.5 | | |
| 80 grams | 150 | 75 | 75 | 40 | 40 | 10 | 4 | 0.8 | | |
| 60 grams | 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 | | |

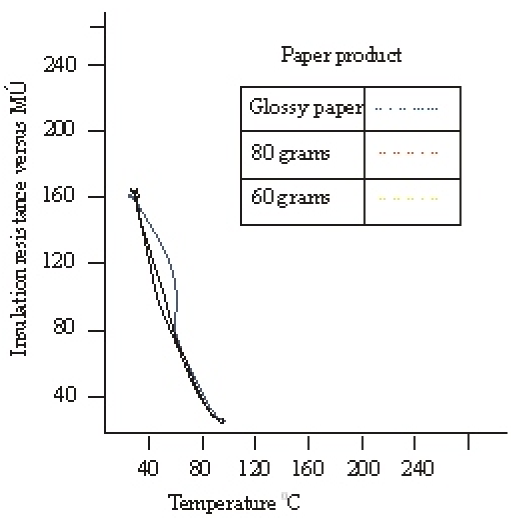


Fig 2c: Insulation resistance versus temperature

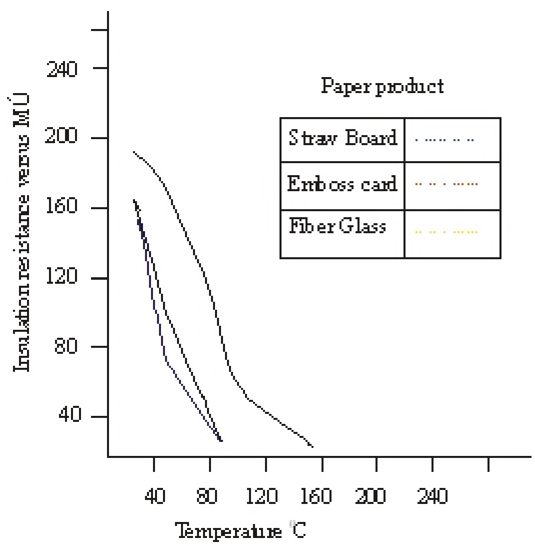


Fig 2d: Insulation resistance versus temperature

## 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, Chipboard, Manila paper, Gloss paper, Strawboard, and Emboss card) are suitable for class Y insulation when impregnated. The other three paper products (Newsprint, 80 gram paper, 60 gram paper) are unsuitable for class Y insulation whether impregnated or not.

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