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# Impact of Sweat Absorption on the Electrostatic Potential Build-Up in Cotton and Nylon Fabric Samples

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**Abstract**

Natural and synthetic fibers can be significant sources of electrostatic build-up in garments. The intrinsic electrical properties of fibers are the result of their chemical composition and polymer structure. Factors such as moisture, temperature, and friction intensity can influence these properties. Due to the insulative characteristics of most fibers, fabrics keep their charge for relatively long periods. This can lead garments to cling to each other, attract dust particles, and create potential hazardous discharge shocks. Moisture increases the electrical conductivity of fibers that leads to a decrease in the build-up of electrostatic potential. The purpose of this study was to identify the impact of absorption of distilled water and electrolyte solution on fabric conductivity and subsequent electrostatic build-up. The study consisted of three components: 1, Comparison of the intrinsic electrical resistance of distilled water to electrolyte solution. 2, Assessment of the electrical resistance of cotton and Nylon fabric samples in relation to decreasing levels of fluid retention. 3, Determination of the electrostatic build-up in Cotton and Nylon fabric samples for dry and wet conditions. The results showed that cotton absorbed more distilled water and electrolyte solution than Nylon. However, the reduction in electrostatic build-up was similar for both. The results indicate that body sweat (electrolyte) can substantially reduce the electrical resistance characteristics of both natural and synthetic fibers and can substantially reduce the generation of electrostatic potential in garments.

*Keywords*: Sweat; electrolytes; electrical resistance; electrostatic potential; synthetic and natural fibers

## 1 Background

Natural and synthetic fibers can be significant sources of electrostatic build-up in garments. The intrinsic electrical properties of fibers are the result of their chemical composition and polymer structure. Factors such as moisture, temperature, and friction intensity can influence these properties [1]. Due to the insulative characteristics of most fibers, fabrics keep their charge for relatively long periods. This can lead garments to cling to each other, attract dust particles, and

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create potential hazardous discharge shocks [2, 3]. Moisture increases the electrical conductivity of fibers that leads to a decrease the build-up of electrostatic potential. The purpose of this study was to identify the impact of absorbing distilled water and electrolyte solution (human sweat) on fabric conductivity and subsequent electrostatic build-up.

## 1.1 Electric Properties

Textile materials used in clothing are generally poor conductors of electricity. Under static conditions, the atoms within a material are neutral as negatively charged electrons are being balanced by the positively charged protons. However, when one of the atoms encounters another atom through friction, electrons are attracted to the nucleus of the other atom. Some of the electrons may be removed altogether through this friction. The material that loses the electrons then becomes positively charged while the other garment layers will develop an opposite charge as they rub against each other. When the layers are separated, one will retain its positive charge and the other a negative charge. This separation of electrons and protons results in static cling. Charged clothing can induce an electrostatic charge on the entire human body. However, moisture absorbed by the fabric can significantly increase the conductivity of the fabric and reduce the build-up of electrostatic potential [4].

## 1.2 Moisture

Sweating is a major source of liquid absorbed by fabrics. The amount of sweat created inside a garment is related to the thermal insulation imposed by a garment, the external environmental temperature and the physical work performed by a person. Studies have addressed the relationship between moisture absorption in textiles and changes in their electrical properties. Fabrics made of different fiber materials have been shown to exhibit different values of electrical resistance. The electrical resistance of fabric samples has been shown to be inversely related to the moisture content in the fabric and the electrical resistance of fabric samples has been shown to be linearly related to the testing distance and exponentially related to the electrolyte concentration [5, 7].

## 1.3 Triboelectric Charging

The electrostatic charge created by friction between two materials is called "triboelectric charging". The amount of charge created by the triboelectric effect depends on the area of contact between two materials, the moisture in the material, the water vapor pressure in the air, the molecular structure of the materials, the friction intensity imposed on the two materials, and other factors [6, 8, 9]. Once a charge is created, it becomes an electrostatically charged material. This charge may be transferred to another material resulting in an electrostatic discharge event. Moisture increases the electrical conductivity of the fibers and can decrease the build-up of electrostatic potential. Fluids containing ions such as body sweat can increase the electrical conductivity of fabrics while fluids with fewer ions such as distilled water do not increase electrical conductivity as much.

Virtually all materials can be triboelectrically charged. How much charge is being generated, where that charge goes, and how quickly, depends on a material's physical, chemical, and electrical conductive characteristics.

### 1.4 Laboratory Tests

Research in triboelectric charging has relied mainly on three main measurements approaches: (1) Measurement of fabric surface resistivity; (2) Measurement of electrical capacitance; (3) Measurement of electrostatic potential.

With the availability of new instrumentation, it is now possible to accurately measure the electrostatic potential resulting from friction between different materials including textiles. This measurement method was chosen for the current study.

### 1.5 Research Objective

The objective of this study was to determine the impact of the absorption of distilled water and electrolyte solution on the electrical conductivity and electrostatic potential build-up in cotton and Nylon fabric samples.

## 2 Methods and Procedures

The study consisted of three components: First, assessment of the intrinsic electrical resistance associated with distilled water and an electrolyte solution simulating human sweat. Second, measurement of the electrical resistance of cotton and Nylon fabric samples with decreasing amounts of moisture content. Third, determination of the electrostatic build-up for Cotton and Nylon fabric samples containing various amounts of distilled water and electrolyte solution.

### 2.1 Electrical Resistance of Liquid

Two insulative trays, 22 cm long, 7 cm wide and 5 cm deep, were used in evaluating the intrinsic electrical resistance of distilled water and electrolyte solution at various electrode separation distances. 300 mL of distilled water serving as a "control" for this study and 300 mL of 6% electrolyte solution were tested. The electrolyte solution contained 600 mg of sodium, 840 mg chloride, 370 mg potassium, and 12 g of sugar. Two copper electrodes were suspended in the liquid and the separation distance changed. Electrode distance separations ranged from 2 cm to 16 cm. The experimental set-up is illustrated in Fig. 1.

### 2.2 Electrical Resistance of Fabrics

Two types of fabric samples were tested: 100% Cotton and 100% Nylon. The samples were obtained from used clothing. Structural features such as yarn count, yarn density and weave density were not determined. Dimensions of all of the fabric samples used in evaluating the changes in electrical resistance associated with changes in the fabric moisture content were 6 cm wide, 22 cm long and had a weight of 7 g. The fabric sample size for the triboelectric tests were 6 cm in width, 42 cm in length and 10 g of weight.

Changes in the electrical resistance associated with the Cotton and the Nylon samples were determined in relationship to the absorbed volume of distilled water, and separately, in relationship

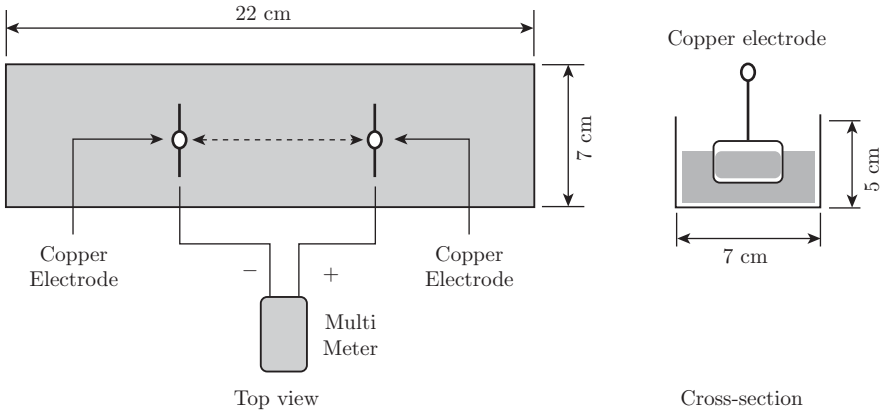



Fig. 1: Experimental set-up used for measuring the intrinsic electrical resistance of distilled water and the 6% electrolyte solution at various electrode separation distances

to the absorbed volume of electrolyte solution. The fabric samples were submerged in either the distilled water or the electrolyte solution for 15 seconds. Samples were then weight and suspended horizontally to dry. Sample weight was measured afterwards at regular intervals at which time the electrical resistance was measured again. The experimental set-up is illustrated in Fig. 2.

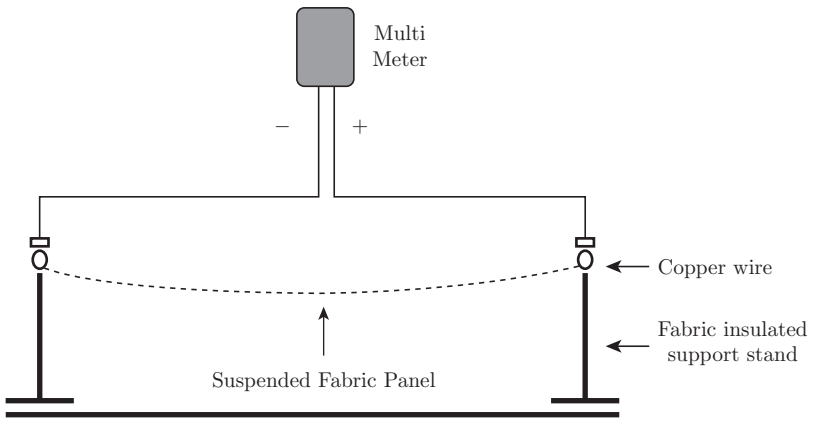



Fig. 2: Fabric support stand used for measuring the electrical resistance of Cotton and Nylon fabric samples at regular time intervals after being submerged in either the distilled water or the electrolyte solution

## 2.3 Electrostatic Potential of Fabrics

The Triboelectric generator previously described (10) was used to measure the electrostatic potential created by the friction of Cotton fabric samples and the Nylon fabric samples. The generator consisted of a non-conductive support frame, a 9 cm diameter variable-speed rotating cylinder (rotor), and a 77 g fabric tension weight. A True-RMS Multimeter recorded the electrostatic potential generated by the fabric materials exposed to the friction of the rotating cylinder. The negative terminal of the Multimeter was placed on the rotor while the positive terminal was attached to the fabric sample. Both cotton fabric samples and the Nylon fabric samples were tested for the dry condition and the wet conditions. The design of the triboelectric friction generator is illustrated in Fig. 3.

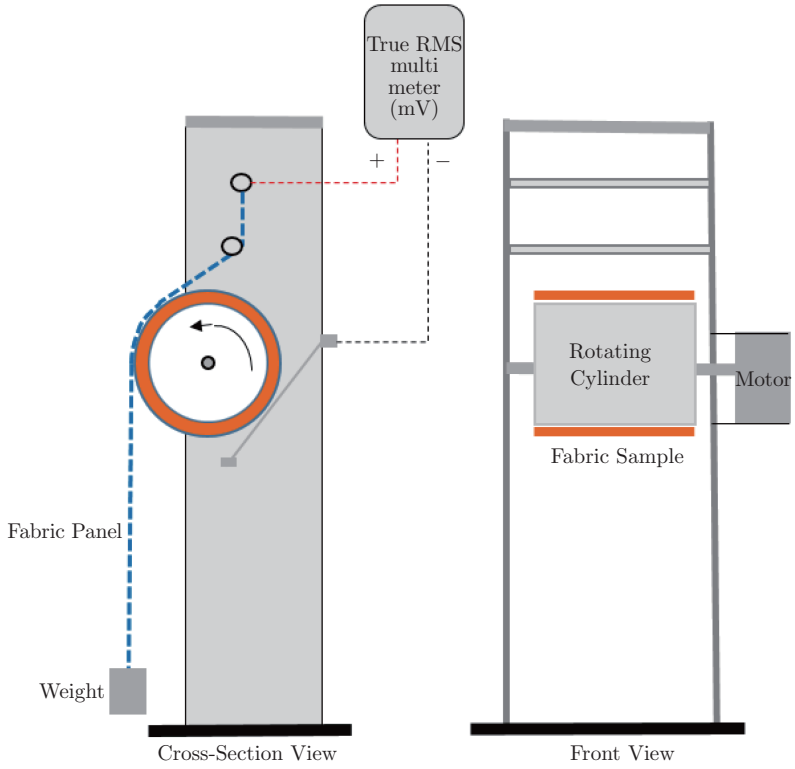



Fig. 3: Triboelectric generator used for measuring the electrostatic charge build-up in Cotton and Nylon fabric samples

# 3 Results

Systematic changes in the electrical resistance associated with the distilled water and the electrolyte solution were observed. While no measurable changes due to electrode separation were observed for the electrolyte solution, a significant increase in the observed electrical resistance was seen for the distilled water. This difference can be attributed to the higher conductivity offered by the electrolyte solution. The electrical resistance profiles for the two liquids are shown in Fig. 4.

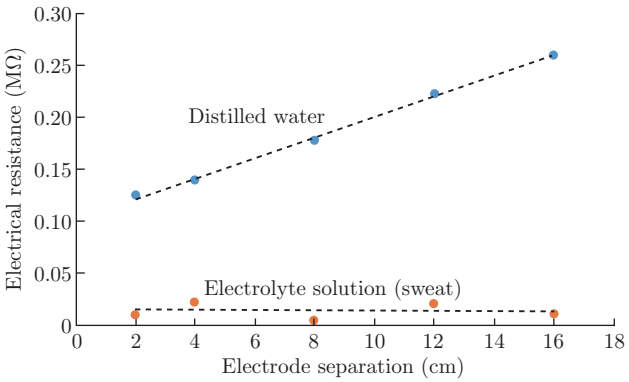



Fig. 4: Electrical resistance profiles for the distilled water and the electrolyte solution in relation to the separation of the electrodes. Resistance values are shown in Mega Ohms (MΩ)

The Cotton and Nylon samples absorbed different amounts of liquid. The amount of distilled

water and electrolyte solution absorbed by the Cotton sample was 8 mL. The total amount of electrolyte solution absorbed by the Nylon sample was only 4 mL. The results showed that the electrical resistance profile decreased linearly as the amount of absorbed distilled water increased in both the Cotton samples and the Nylon samples. Such a change was not observed in relationship to the electrolyte solution.

The electrical resistance profiles for the Cotton sample containing distilled water and the electrolyte solution are illustrate in Fig. 5. The electrical resistance profile for the Nylon samples containing distilled water and the electrolyte solution is illustrated in Fig. 6. The electrical resistance of distilled water absorbed by the Cotton was significantly higher than the resistance exhibited by the distilled water absorbed by the Nylon sample. However, there was very little difference between the Cotton sample and the Nylon sample in the electrical resistance values seen for the electrolyte solutions absorbed by the two fabric types.

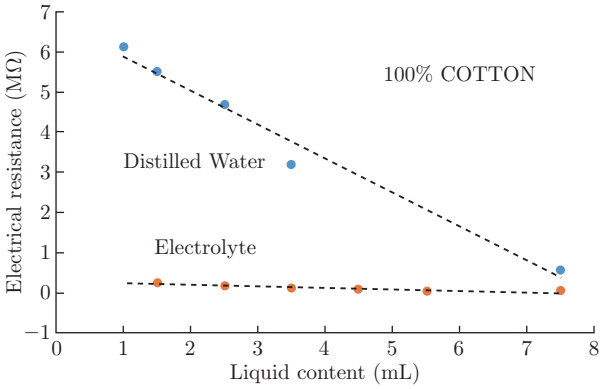



Fig. 5: Electrical resistance profiles of the Cotton samples containing distilled water and the electrolyte solution. Resistance values are shown in Mega Ohms (MΩ)

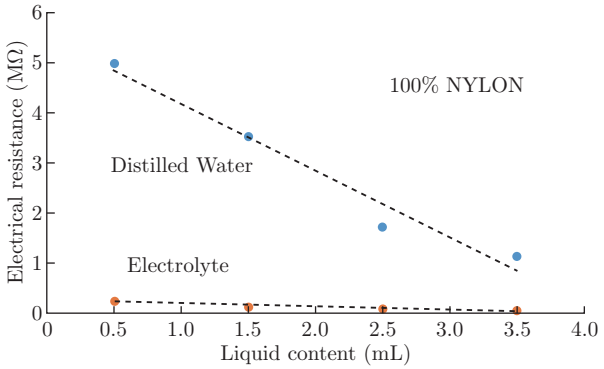



Fig. 6: Electrical resistance profiles for the Nylon samples containing distilled water and the electrolyte solution. Resistance values are shown in Mega Ohms (MΩ)

Table 1 summarizes the electrostatic build-up observed in the Cotton samples and Nylon samples containing distilled water and electrolyte solution. The data show that for both fabric types, the electrolyte solution provided a greater reduction in the electrostatic build-up than the distilled water. While the electrolyte provided a reduction of 81% and 89%, the distilled water provided a reduction of 75% and 89%.

Table 1: Summary of electrostatic potential build-up observed in the Cotton and Nylon fabric samples containing distilled water and electrolyte solution

| Fabric Sample | Liquid | Electrostatic Potential (mV) | Change in Electrostatic Potential (%) |
|---|---|---|---|
| 100% Cotton | Dry | 64.6 | – |
| | Distilled Water | 15.8 | 75% |
| | Electrolyte Solution | 12.4 | 81% |
| 100% Nylon | Dry | 91.6 | – |
| | Distilled Water | 14.7 | 84% |
| | Electrolyte Solution | 10.4 | 89% |

# 4 Limitations

The fabric samples evaluated in the experiments were obtained from previously worn clothing and may have been impacted by their previous use. Furthermore, the structural fiber characteristics such as yarn count, weave type and weave density could not be determined. Such variables may have influenced their electrostatic characteristics. Controlling such variables in the future will allow a more precise differentiation of a fabric sample's electrical resistance and propensity for creating an electrostatic charge due to friction with other fabric types.

# 5 Conclusions

This study found that Cotton fabric samples retained larger amounts of both distilled water and electrolyte solution than Nylon fabric samples. However, the magnitude of the electrical resistance for both fabric types was similar. The electrostatic build-up in the Cotton fabric samples was similar to the Nylon fabric samples. This suggests that both Cotton and Nylon fabrics can display substantial reductions in electrostatic build-up when exposed to human perspiration (sweat) and water. This should be considered when planning future applications and use of fabrics made of various combinations of natural and synthetic fibers.

# References

[1] Adler MM, and Walsh WK, Mechanisms of Transient Moisture Transport Between Fabrics. Textile Res. Journal, 1984, 54(5): 334-338.

[2] Verschave R, Firmin. R. Hazards of Static Electricity in Work Clothing, J. Oil and Color Chem. Assoc. 1980, 63(7) 287-289.

[3] Crow RM. Static Electricity: A Literature Review. Canadian Defence Research Establishment, Ottawa. 1991: PCN, 051LC.

[4] Gonzales JA. Development of a Qualitative Method for Fiber Idantification using Electrostatic Characterization. AATCC International Conference Poreceedings, 2001: 247-254.

[5] Hersh SP, Montgomery DJ, Static Electrification of Filaments:Theoretical Aspects. Textile Res. Journal, 1956, 26: 903-913.

[6] Lobel W. Antistatic Mechanism of Internally modified Synthetics and Quality Requirements for Clothing Textiles. Proceedings of the Institute of Physics Conference. 1986, 85(2): 183-186.

[7] Wang Z, Xu W, Li W, et al., Study on the Electrical Resistance of Textile under Wet Conditions.Textile Res. Journal, 2009, 79(8): 753-760

[8] Crow RM, Osczevski RJ. Interaction of Water with fabrics, Textile Res. Journal, 1998, 68(4): 280-284.

[9] Rousselle MA, Thibodeaux DP, French AD. Cotton Fiber Properties and Moisture: Water of Inhibition, Textile Res. Journal, 2005, 75(2): 177-183.

[10] Reischl U, Mijovic B, Assessment of Electrostatic Potential Resulting from Friction between Fabric Samples made of Natural and Synthetic Fibers. Proceedings of the 14th Textile Bioengineering and Informatics Symposium, 2021: 340-344.