STUDY ON THE MEASUREMENT UNCERTAINTY BEHAVIOUR OF SURFACE AND VOLUME RESISTIVITY EQUIPMENT

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A report submitted
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DECLARATION

I declare that this thesis entitled " STUDY ON THE MEASUREMENT UNCERTAINTY BEHAVIOUR OF SURFACE AND VOLUME RESISTIVITY EQUIPMENT " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : NUR AQILA BINTI HASAN

Date : 2.7.2021

APPROVAL

I hereby declare that I have checked this report entitled "STUDY ON THE MEASUREMENT UNCERTAINTY BEHAVIOUR OF SURFACE AND VOLUME RESISTIVITY EQUIPMENT" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours.

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

I Specially dedicated to God Almighty my creator and my source of inspiration. To my beloved parents and families, supervisor, panel and fellow friends who always encouraged and give me the strength to finish that which I have started.

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ABSTRACT

Resistivity is an important in any material that conduct an electricity as it enables the right materials to be used in the right places in the electrical components. Resistivity can define as the measured of resistance that across a material and it is determined based on the physical dimensions of the material. The resistivity of a material depends on a several factors, such as applied voltage, electrification time and environmental condition such as temperature and humidity. Most of the electrical resistivity measurement is used as a quality control test. In order to determine the resistivity of a material, the uncertainty of measurement was introduced. The purpose of this measurement uncertainty is to determine the range of the possible value can vary within the true value of the measurement lies. The uncertainty of measurement is the doubt that exists in the result of many measurements. The quantitative measurements are performed each day and the role of measurement uncertainty becomes more important while accessing to the conformity. Measurement uncertainty is critical to risk assessment and decision making. Some of the decision make based on the reports that containing the quantitative measurement data. As according to the National Institute of Standards and Technology, no measurement that complete without accompanying statement of the associated amount of the uncertainty. In this research paper, both of surface and volume resistivity was conducted on Monroe Electronic Model 272A. There are two types of material with three sample specimen of material itself were tested and analyzed in order to determine the measurement uncertainty of the equipment. Therefore, the purpose of this research is to improve the quality of the measurement of surface and volume resistivity equipment by analyzing the measurement of uncertainty of surface and volume resistivity equipment.

ABSTRAK

Ketahanan adalah penting dalam sebarang bahan yang mengalirkan elektrik kerana ia membolehkan bahan yang betul digunakan di tempat yang betul dalam komponen elektrik. Ketahanan boleh didefinisikan sebagai ukuran rintangan yang melintasi bahan dan ditentukan berdasarkan dimensi fizikal bahan. Ketahanan bahan bergantung pada beberapa faktor, seperti voltan terpakai, masa elektrik dan keadaan persekitaran seperti suhu dan kelembapan. Sebilangan besar pengukuran resistiviti elektrik digunakan sebagai ujian kawalan kualiti. Untuk menentukan ketahanan bahan, ketidakpastian pengukuran diperkenalkan. Tujuan ketidakpastian pengukuran ini adalah untuk menentukan julat nilai yang mungkin boleh berbeza-beza dalam nilai sebenar pengukuran terletak. Ketidakpastian pengukuran adalah keraguan yang wujud dalam hasil banyak pengukuran. Pengukuran kuantitatif dilakukan setiap hari dan peranan ketidakpastian pengukuran menjadi lebih penting semasa mencapai kesesuaian. Ketidakpastian pengukuran sangat penting untuk penilaian risiko dan membuat keputusan. Sebilangan keputusan dibuat berdasarkan laporan yang memuat data pengukuran kuantitatif. Seperti yang dinyatakan oleh Institut Piawaian dan Teknologi Nasional, tidak ada pengukuran yang lengkap tanpa menyertakan pernyataan mengenai jumlah ketidakpastian yang berkaitan. Dalam makalah kajian ini, kedua-dua ketahanan permukaan dan isipadu dilakukan pada Model Elektronik Monroe 272A. Terdapat dua jenis bahan dengan tiga sampel spesimen bahan itu sendiri diuji dan dianalisis untuk menentukan ketidakpastian pengukuran peralatan. Oleh itu, tujuan kajian ini adalah untuk meningkatkan kualiti pengukuran peralatan ketahanan permukaan dan isipadu dengan menganalisis pengukuran ketidaktentuan peralatan ketahanan permukaan dan isipadu.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

Volume resistivity can represent as an insulating material's leakage current that pass through its body. Meanwhile, the surface resistivity is the resistance to leakage current along an insulating material's surface. Basically, resistivity is determined based on the physical dimension of the test sample. Laboratory measurements always involve with an uncertainty which must be considered when analytical results are used as part of the basis for making decisions. In every measured result that reported by a laboratory should be accompanied by an explicit uncertainty estimate. Uncertainty is a statement of the limits of a range of value within which the true value of the measurements is expected to lie in relation to the recorded results and the probability of the true values lying within these limits. The role of measurement uncertainty becomes more important when assessing the conformity. It is the doubt that exists about the result of any measurement. Basically, there always a margin of doubt about any measurement that were taken. Many factors that affect the uncertainty of test data produced by testing machine. The Monroe Electronics Model 272A Portable Surface Resistivity/Resistance Meter were introduced to provide faster repeatable measurements of both surface resistivity and resistance to the ground in the one versatile instrument. It improves accuracy and digital readout make it ideal for checking and evaluating static control product such as static dissipative bags, mats and work surface and resistance of work surface to the ground.

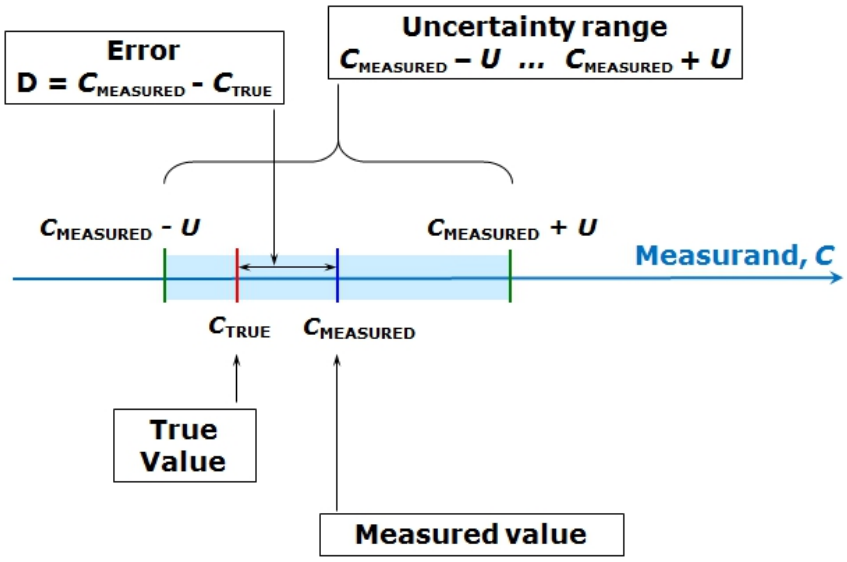

Figure 1.1: The relationship between true value, measured value, error and uncertainty[4].

1.2 Problem Statement

Uncertainty of measurements is about quality. Every measurement is subject to some uncertainty. A single measurement of a quantity has been often sufficient for the purpose of the measurement being taken. But somehow, the uncertainty of a single measurement is limited by the precision and accuracy of the measuring instrument. The measurement uncertainty on the measuring equipment is determined by a multitude of factors such as resolution, stability and reproducibility of the equipment. All of this factor gives the difference value of measurement uncertainty. The character of measurement uncertainty is important because a realistic uncertainty measurement can provide for actual variables that may be encountered, possible solution can be provided and procedures can be enacted to account for those variables. Also, a realistic uncertainty also lends greater credibility to the measurement data being generated. The purpose of this research is to apply measurement uncertainty in the surface and volume resistivity testing accuracy analysis equipment.

1.3 Research Motivation

Error in the measurements is the difference between the measured value and the 'true value' of the structure being measured. Meanwhile, the uncertainty is quantification of the doubt about the measurement result. Measurement uncertainties can come from the measuring instrument, the temperature of the environment, from the operator, and the other source. Uncertainties can be estimated using statistical analysis of a set of measurements, and using other kinds of information about the measurement process. The performance of the method is then quantified in term of precision and trueness. Also, there some rules on how to calculate the overall estimation which is traceable calibration, careful calculation, good record keeping and checking. By using this good practice rule it will help to reduce the measurement uncertainty. The aims of this research to apply measurement uncertainty method for the testing accuracy equipment.

1.4 Objective

An outcome from this research:

I. To study the process of evaluating the measurement uncertainties of equipment.

II. To analyze the measurement uncertainties of surface and volume resistivity equipment.

1.5 Significant of the Research

The proposed by this research will provides the precision and the accuracy in the measurement uncertainty of the surface and volume resistivity. There are some beneficial and significant elements of the research is expected to provide. First, the behavior of the measurement uncertainty can help to increase the precision of the measurement. So that, the percentage of the measurement error can decrease. Note that, wrongly prescribe error can lead to over- or under-fitting of the data. Next, from this study it will help to improve the accuracy of the reading of the instrument. In this research, it also can help to develop the methodology of determining the result of

measurement uncertainty for surface and volume resistivity. Thus, the expectation on this research, it will help to enhance the method and approaches for the measurement uncertainty behavior of surfaces and resistivity and to make a good quality of the measurement in the future.

1.6 Scope of the Research

This research will be focused on the behavior of the measurement uncertainty on the surface and volume resistivity. This volume and surface resistivity test will be conducted on the Monroe Electronics Model 272A Portable Surface Resistivity/Resistance Meter. There are 2 types of material that used for this testing, which is glass and thermally upgraded kraft paper. This research was followed the *American National Standard* (ASTM) D257 and ISO/IEC 17025:2005.

1.7 Organization of the Scope

This report will be divided into five parts. Chapter 1 is the introduction about the research. In this chapter will consist an overview about the research, such as the background of the research, problem statement of the research, motivation of the research, an objective and scope of the research. Next, chapter 2 is the literature review. This chapter will review about the sample material that used for the surface and volume resistivity testing purpose, the important elements for the sample material selection, the measurement uncertainty and the standard that applied to the testing. Chapter 3 of this report will be the methodology about the research. In this chapter will include the equipment used for the surface and volume resistivity test, the apparatus of the testing, the flowchart of the testing and the measurement uncertainty for the surface and volume resistivity test. The next chapter will be chapter 4 which is the results and discussions about the research. In this chapter will be discuss the measurement uncertainty in the collected volume and surface resistivity data. Some of the calculation may be involved in this chapter for the measurement uncertainty purpose. Next, chapter 5 about the conclusion and the recommendation of the research. This chapter will discuss the overall conclusion about this research and the recommendation to improve this research to get better in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Insulator

All of the electrical system requires an insulation to protect the short circuit and the current from leaking. Insulator also can described as having low electrical conduction, so that the electricity does not allow to pass through. This material also does not have any free electrons because of the strong covalent bond. It also has a high resistivity compared to the other material. Insulator must be able to withstand the electrical stress also the certain stress during manufacturing, storage and operation. Its performance were depending on its operating temperature. Insulation are widely used in the transformer, cable and bushing and switches. By referring to the Model 272A's range, this equipment used to perform resistivity test on the insulator materials.

2.1.1 Glass

Technical glasses are a special glass manufactured in a variety of special shapes such as tubes, rods, hollow vessels, flat glass or powder glass. A purely glass for an optical application are usually distinguished from these technical glasses by their special manufacturing process by their special compositional ranges.

In simpler language, the term of glass designated a transparent substance, processing the properties of hardness, rigidity and brittleness, and apart from transparency. In general, a glass is an inorganic product of fusion which has cooled to a rigid condition without crystallization [ASTM C162]. Glass is usually formed a solider from the melting stage. The cooling process happens so rapidly, so that the crystallization does not have time to occur. With the decrease of the temperature, the viscosity of the glass continues increase and as a result, a progressive freezing of the liquid to its final solider. For many years, the idea of combining two or more different components to produce a new material with unique properties such as Borosilicate glasses, Aluminosilicate glasses, Aluminoborosilicate glasses and etc.

Figure 2.1: The glass sheet used for testing.

2.1.2 Thermally Upgraded Kraft Paper

As a high capacity of power network rise, the advancement has been made in the thermal endurance of cellulose-based insulating papers. Since early 1900's, cellulose-based insulating materials are commonly called kraft papers have been widely used in oil-filled electrical distribution equipment.

Because of its low cost and reasonably good performance, kraft paper continues to be the insulation choice in virtually all oil-filled transformers. However, the cellulose polymer is subjected to the thermal degradation and vulnerable to oxidative and hydrolytic attack. The most recent improvement is occurring in the late of 1950's which is "Thermally Upgraded" kraft paper was introduced. In this thermal upgrading process, chemically treating the paper involved with a nitrogen-based compound such as dicyandiamide. The function of this chemical treatment is to stabilize the hydroxyl radicals present on the cellulose molecule, thus reducing the tendency toward hydrolysis. This thermal upgrading process raises the continuous operating temperature that suggested by IEEE C57.91 from 95^{o}C to 110^{o}C. With the long-term life, some of heat-stabilized papers has been found to be up to 10 times longer than the standard papers.

Figure 2.2: The thermally upgraded kraft paper used for testing.

2.2 Electrical Properties

An electronic material plays a vital role in the technology today. From the science aspect, the electrical properties can characterize the two main processes which are electrical energy conduction and the electrical energy storage. In this research, the focus will go to the electrical energy conduction of the material.

2.2.1 Surface Resistivity

The surface resistivity is the resistance that varies between the two opposite sides of the material. The surface resistivity can be defined as a fixed surface length's electrical resistance of an insulating material. The surface resistivity usually represents as ohms per square as the square unit of dimension on the surface of the material use. For this measurement, it does not take physical dimension such as the volume resistivity that need to determine the area and thickness of the specimen. The value of measured surface resistivity at any square of the surface material is independent towards the size of the specimen.

Since it only determines the surface resistivity, only one physical measurement that required. The surface resistivity is measured between electrodes along the insulator material surface. Surface resistivity is measured by applying a voltage potential across the surface of the insulator sample. In the material testing, this measurement can determine the surface resistivity of plastic. For static electricity dissipation such as electronic manufacturing, low surface resistivity is ideal.

$$\rho_s = R_s \frac{P}{g} \quad (1)$$

Where,

ρ_s = Surface resistivity

P = Perimeter of the measuring electrode

g = Dimension of space between guarded electrode and ring electrode

$$g = \frac{D_1 - D_2}{2} \quad (2)$$

$$D_0 = D_1 + g \quad (3)$$

Where,

D_1 = Diameter of guarded electrode

D_2 = Diameter of ring electrode

D_0 = Diameter of space between

After derive the formula,

$$\rho_s = R_s \frac{2\pi}{\ln \frac{D_2}{D_1}} \quad (4)$$

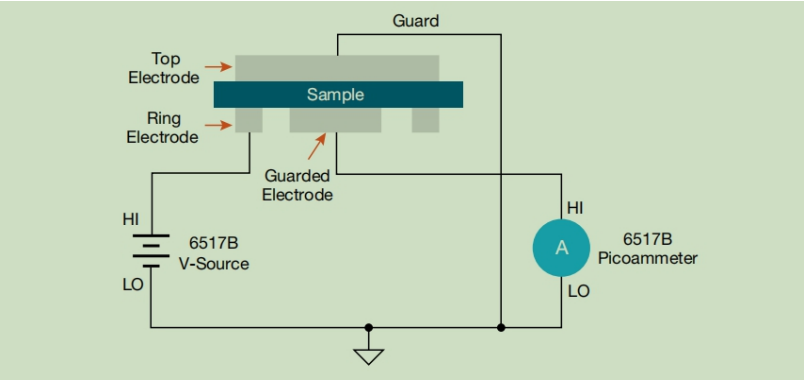

Figure 2.3: The schematic connection of surface resistivity [1].

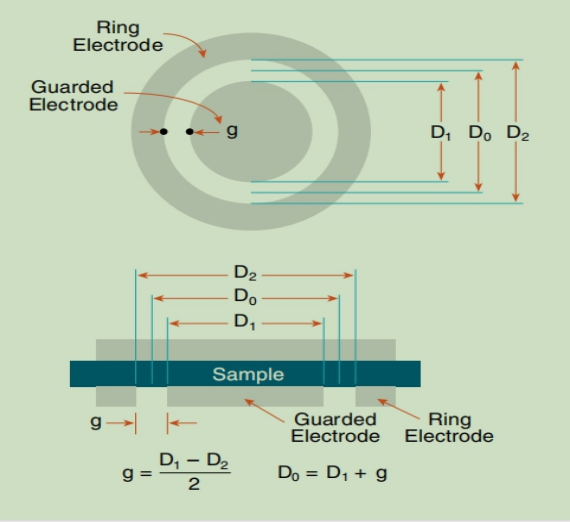

Figure 2.4: The surface and volume resistivity measured electrode [1].

2.2.2 Volume Resistivity

Each of insulator that used for electrical and electronic purpose should go to this volume resistivity. Besides the surface resistivity, volume resistivity is one of the basic parameters for insulating material. The volume resistivity can be defined as the electrical resistance that through a cube of insulating material. The volume resistivity can be express as ohm-centimeters as the electrical resistance through a one-centimeter cube of the insulating material.

The volume resistivity is measured by applying a voltage potential across an opposite side of the insulator sample and measuring the resultant current through the sample. The electronic device contains a different type of chemical meant to insulate. The purpose of the volume resistivity testing is to ensure the electricity that travels through these components as intended. Determined the volume resistivity of electrical consumer products is an important part of safety standard testing. The volume resistivity in conductive pastes and other electronic components can indicate contamination if the desire level of resistivity isn't achieved. Basically, the volume measurement cannot measure directly as surface resistivity, so from the measured volume resistance and determining the geometrical dimension of material, the volume resistivity can be determined from the calculation.

$$\rho_v = R_v \frac{A}{t} \quad (5)$$

Where,

ρ_v = Volume resistivity

A = Effective area of the electrode

t = The average thickness of the sample specimen

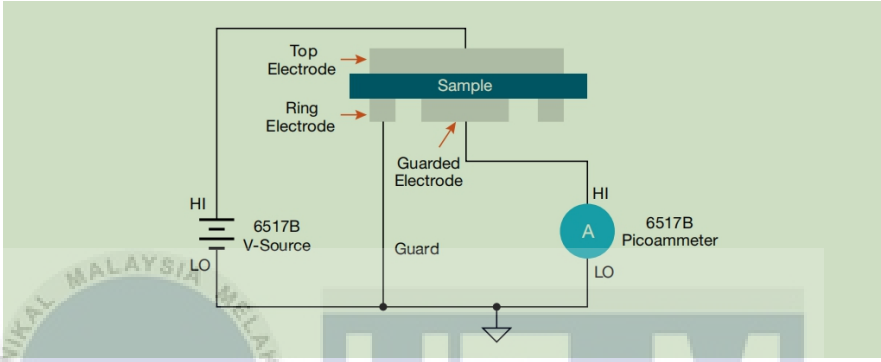

Figure 2.5: The schematic connection of the volume resistivity[1].

2.3 Mechanical Properties

In the mechanical properties of the insulating solid material, there are several factors that will affect the reading of measurement such as density, moisture absorption, hardness of the surface and uniformity.

Firstly, is a density of the material. Instead of weight, the basis of volume was used in the electrical insulation. For example, the low density of insulating material is more suitable especially for a small portable equipment and an aircraft components. Next, the moisture absorption of the insulating material. The electrical resistance depends on the temperature and air humidity which means the higher value of temperature and humidity, the less accurate result that will produce during the measurement will be. The water that is contained in the air will lowers the electrical resistance. With this absorption properties, some of the chemical and mechanical effects such as swelling and warping the corrosion may occur. Next, the hardness of the surface is one of the important mechanical properties. The hardness of surface helps the insulating material to resist surface scratching and absorption while the