Effect of Electrodes on Rubber Insulating Glove

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Abstract— **This paper presents experimental procedures and data for comparative evaluation of the insulation value of the protective rubber insulation glove. This paper focused on the usage of Class 2 gloves. The objective of this research is to observe and analyze the characteristic of the rubber glove when it is given potential from different source of contact. The different electrodes used in this research were compared with each other in order to observe the breakdown voltage and also the tan δ. Experimental results for various types of electrode tested were analyzed. Collected results indicates that, different type of electrodes will yield different results of withstand levels for the gloves including the breakdown voltage and dielectric properties. This research only covers the experimental setup of normal test vessel due to the absence of the oil bath vessel. Hence the effects of corona and flashover have to be considered. This lead to conclusion that electrical performance of rubber glove will achieve breakdown voltage faster when it is in contact with flat circular electrode.**

Keywords— **Rubber glove, rubber, glove.**

INTRODUCTION

Electrical safety has been a rising concern of many parties nowadays. Safety equipment manufacturers are trying to invent and produce equipments that can help the industry and electricians in order to reduce the amount of injuries and fatalities during conducting related electrical work. Among the regular safety equipments that should be used by employee are safety gloves, safety helmets, safety shoes and others. All these equipments can be classified as personal protective equipment (PPE). By definition, process of minimizing or eliminating the risk of injury or fatality from electrical hazards is defined as electrical safety. According to survey which has been done on some sites, there are still employees who are not concern on the importance of voltage-rated gloves and arc flash protection[1].

Therefore, this analysis will focus on safety gloves used by electrical-related employee who has possibility of being in contact with some types of electrical fault such as flashover and arching. Employees of electrically related field need special equipments that can help to isolate them from electrocution and also discomfort due to voltage induced currents during handling energized equipment[2]. When an employee do not use a protective glove while maintaining live line, they are directly connected to the energized line or equipment[3]. Dielectric material that exist in the protective glove will insulate the employee from the line potential[3] thus reducing the probability of being electrocuted.

Basically, the electric field strength that exist around the glove is totally depending on the potential of the worker[3]. This means that when the worker is being isolated from the ground, the electric field strength that flow around the employee is much lower compared to when the employee is connected to the ground. Since the human body is a good current conductor, it can let current to flow in the blood vein and when the human body is grounded, inadvertently, it will complete an electric circuit. Thus, grounded employee will cause high electric field strength and consequently leakage current that flows inside human body will be increased[3].

For this analysis, several type of test will be employed in order to achieve the objective of this research. Generally, tests are carried out on dielectric samples such as the measurement of permittivity, dielectric loss, and the dielectric strength of the material[4]. In general, there are two types of test source for conducting these tests which are the alternating current (AC) and direct current (DC) test. There are also other types of test that can be conducted other than those stated above such as the insulation resistance test, withstand test, flash-over test and others which are suitable to be employed to the test subject. However, breakdown voltage test of finished insulating gloves must be determined by using experimental testing[5].

There are several types of experimental setup on conducting the solid insulator tests. One of the experiments to be conducted on the protective glove is by using oil bath. This method is particularly useful for reducing the effects of water corona and water turbulence from the analysis, yielding number of statistical data point for statistical analysis and many section of the glove can be used to test the uniformity of the glove material[5]. However, since the lab facilities do not have equipments for oil bath vessel test, this research will be conducted with normal test vessel. Due to this matter, effects of corona discharge will be taken into account.

METHODOLOGY

This experiment is conducted mainly to focus on the functionality of the safety glove and its effectiveness under several conditions as will be discussed later. This section will discuss briefly on how the testing procedure of the safety glove was conducted during the entire project.

First of all, the gloves were cut into small samples which are then categorized for test conducted according to the type of electrode in which it will make contact with during the actual usage. Each sample was measured at 1inch x 1inch and cut off from the gloves. It is to be noted that the sample is being cut from the large-flat area of the glove. This is to ensure that the samples are all identical. This was done in order to ensure that the physical condition of the samples will not influence the reading.

As the main objective of the test is to examine the effects of the electrodes to the effectiveness of the glove, three types of electrodes are chosen to be used in the research.

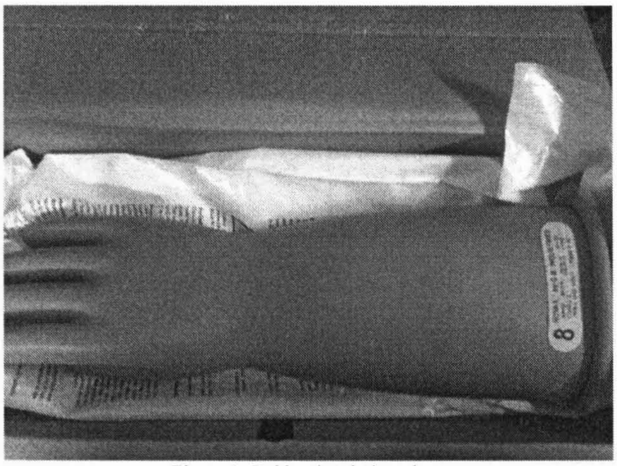


Figure 1: Rubber insulating glove

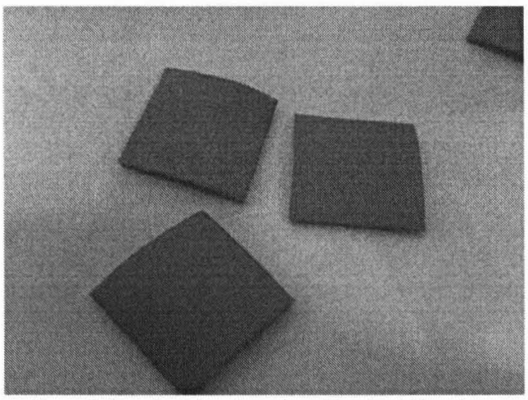


Figure 2: Samples taken from the rubber insulating glove

Generally, the measurement circuit used to measure all the parameters stated in this research was the Schering Bridge. The Schering Bridge circuit was chosen for its capability to measure tan δ and the capacitances of the samples.

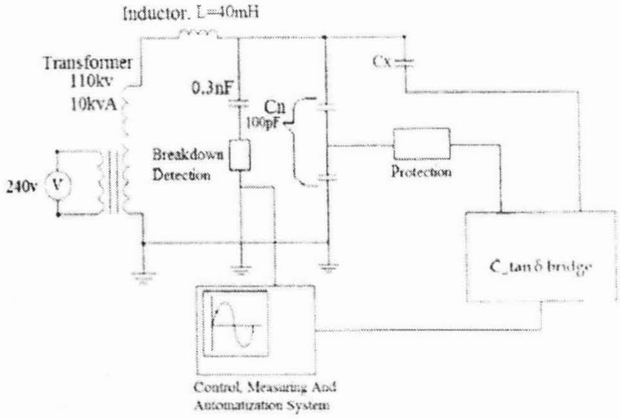


Figure 3: Schematic diagram of Schering Bridge

The standard lossless capacitor, Cn has an accurately known capacitance and connects the earth side at low-voltage bridge arms together with test object capacitance Cx. In the high-voltage area, the applied voltage is energized and passes through Cn and Cx. Standard resistor R3, calibrated impedances R4 and C4 are placed in low voltage test area for bridge balancing. At balance condition, the value of sample capacitance,Cx is obtained form

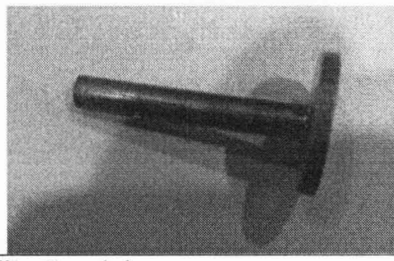
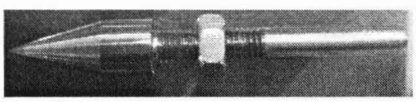
$$C_x = \frac{R4}{R3} C_n \quad (1)$$

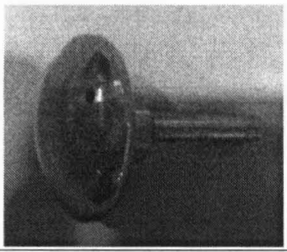
and tan δ is determine by

$$\tan \delta = \omega R_4 C_4 \quad (2)$$

As stated before, this research will acquire the usage of three types of electrode which are the flat-rounded, cone shaped and hemisphere shaped electrodes. Each electrode will result in different effects to the sample.

Table 1
Types of electrode used in this research

Type of electrode	Function
i) Flat-rounded electrode 	Used to supply electron to the sample thoroughly and fairly to its whole surface.
ii) Coned shape 	Use to let the electron transfer at only a certain point. Thus this can be used to simulate

iii) Hemisphere shaped 	Use to simulate contact with energized unsmooth surface.

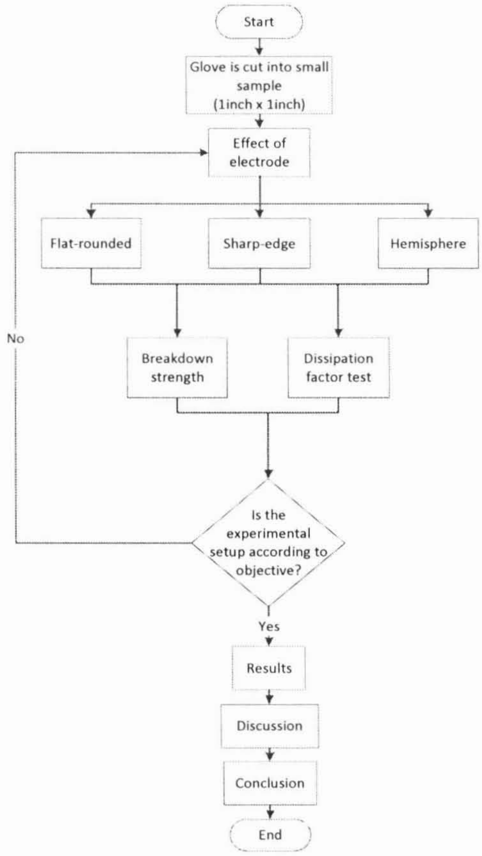


Figure 4: Process flowchart

EXPERIMENTAL PROCEDURE

Measuring tangent delta of a sample needs the use of a Schering bridge circuit. Hence, choosing the right value of circuit components will produce balanced bridge which will ease the whole experiment. Therefore value of inductor of 40mH was chosen to connect between the transformer and the first capacitor which is 0.3nF. Both components will act as filter for the circuit which will also control the number of times through the circuit. The Module-Pressed Compressed gas standard type 100 capacitor dividers (MCP100) which is used to converts the high AC voltage to a more typical level under 1000V.

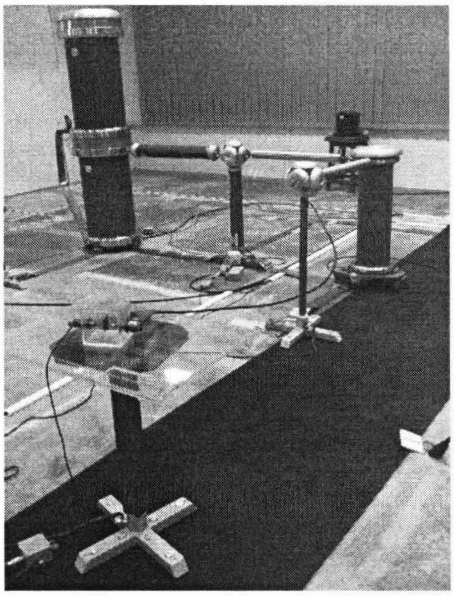


Figure 5: Actual laboratories setup

The samples were tested on several types of electrodes. Hence the result for each of the electrode type was analyzed by using ICMcompact. It is to be noted that ICMcompact is the main control scheme for measurement and automatization system whereby value of test voltage and their increase is set.

The test parameters which are not set at the measurement control and automatization system equipment are listed in the table below which includes the step voltage during the experiment.

Table 2
Parameters of the experiment setup

VOLTAGE		STRESS	
Limit Voltage [kV]	30	Tolerance of step voltage [%]	2
Final Voltage [kV]	25	No. of cycles	>5
Start Voltage [kV]	5	Duration of step	00:01:00
Step Voltage [kV]	1	Break Duration	00:00:05
Rate of Voltage Rise [kV/s]	3	Go Down	

The test samples were place in between the electrodes one-by-one as the tests are being conducted. The test mode for this research is manual which is to be set at the measurement control and automatization system since this research will require the observation of tangent delta. The manual mode will require user to step-up test voltage manually after each test. The step-up voltage set for this research used is 200 kV.

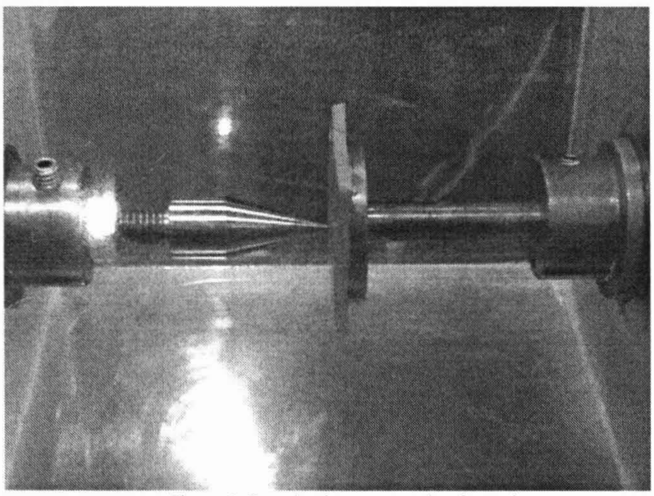


Figure 6: Sample placement at the electrode

RESULTS AND DISCUSSION

Since the Schering Bridge circuit used in this research was able to obtain the value of dissipation factor of the material, this research was extended to analyzing the dissipation factor of the samples. Both parameters which are the breakdown voltage and the tangent delta values are important in order to analyze the effectiveness of the material which in this case is the rubber glove. Twelve samples were used in this research whereby each test will be repeated four times for each of these samples in order to see if there are any variations on readings of the tests.

Table3
Breakdown voltage with different electrodes

Type of electrode	Sample's reading (kV)				Average (kV)
	A	B	C	D	
Flat circular	5.7	6.9	5.5	5.4	5.875
Cone shape	13.9	17.5	15.9	18.7	16.5
Hemisphere shape	8.61	8.02	7.89	8.74	8.315

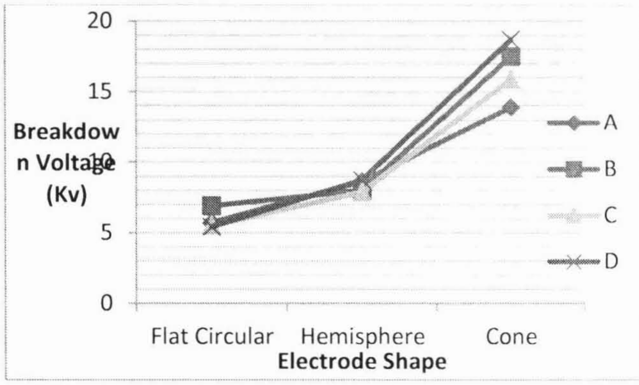


Figure 7: Graph of breakdown voltage for each electrode shape

From the table above, it is observed that there are differences in the breakdown voltage with each of the electrode. Based on this research, the results showed that cone shaped electrodes increases the breakdown strength of the samples while flat-circular electrodes causes lower breakdown strength on the samples.. Among the factor which can be considered is the surrounding condition whereby the humidity of the air inside the lab and also factor that could come from the electrode such as dirty electrode or oxidation process which already occur at the electrode. This factor is observable at the hemisphere electrode which the condition is not fit for the test since oxidation process already occurred at the electrode.

A. Testing with flat circular electrode

The total number of sample being used in this test in total is four as it was repeated for four times after each breakdown has occurred.

Table 4
Value of tangent delta for flat circular electrode

Test voltage (kV)	Samples				Average
	A	B	C	D	
5	0.396	0.553	1.22	-	0.5423
7	-	0.667	-	-	0.1668

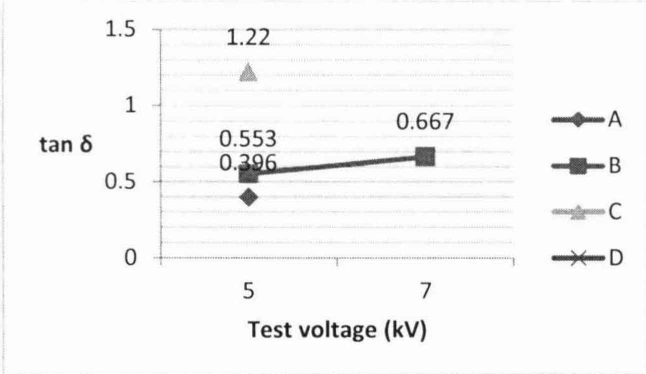


Figure 8: Graph of tan δ versus test voltage

Based on the results shown above, the values of tangent delta for sample A is 0.396 which is lower compared to values of tangent delta from specimen B which is 0.553 and specimen C is 1.22 when they are tested at 5 kV. During this stage, the specimen D did not raise any value of tangent delta because of the specimen already achieve its breakdown limit at 5.4 kV. Hence there is no value of tangent delta produced by the tangent delta measuring equipment. This condition repeated at test voltage of 7 kV whereby the specimen A, B, and D did not give any balanced condition for the equipment to produce the tangent delta value.

B. Testing with cone shape electrode

Table 5
Value of tangent delta for cone shape electrode

Test voltage (kV)	Samples				Average
	A	B	C	D	
5	0.835	1.468	1.295	0.751	1.0872
7	0.940	1.527	1.465	0.814	1.1865
9	0.942	1.663	1.612	0.952	1.2923
11	1.000	1.552	1.717	0.968	1.3093
13	1.123	1.638	1.726	1.322	1.4523
15	-	1.671	1.768	1.563	1.2505
17	-	1.695	-	1.547	0.8105
19	-	-	-	1.815	0.4538

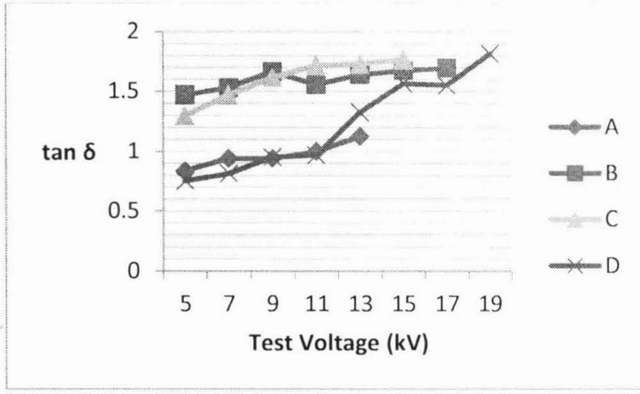


Figure 9: Graph of tan δ versus test voltage

Since the objective of this research is to study the effects of the glove under several types of electrodes, changing the electrode into cone shape with flat circular electrode brings another story. As shown in the table above, values of tangent delta produced by each sample increased as the test voltage increases.

C. Testing with hemisphere shape electrode

Table 6
Value of tangent delta for hemisphere shape electrode

Test voltage (kV)	Samples				average
	A	B	C	D	
5	1.7111	1.6443	1.0961	1.1112	1.3907
6	1.2741	1.3674	0.9172	1.4913	1.2639
7	1.098	1.3705	0.8711	1.0662	1.1015
8	1.0981	1.3442	-	1.0854	0.8819

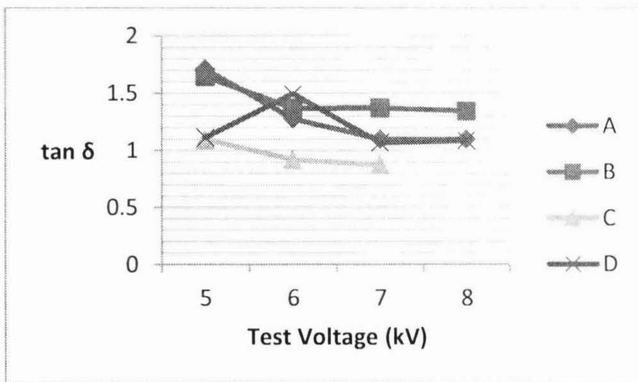


Figure 10: Graph of tan (δ) for hemisphere electrode

The last test conducted in this research was to test the samples with hemisphere and flat-circular electrode. As observed, the values of tangent delta of the samples decreased as the voltage increases.

Table 7
Value of tan δ by each electrode

Type of electrode	Average value of tan δ
Flat circular	0.3546
Cone shape	1.1053
Hemisphere	1.1595

Based on the results obtained above, it is known that electrode with less surface contact area with sample do raise a better voltage breakdown value compared to electrode that has larger surface contact area. It is to be known that by theory, smaller contact surface area will produce faster breakdown value compared to larger contact surface area. This is believed to be caused by the reaction of the electrons towards the electrode. Larger flat area will cause the electron to disperse widely throughout the area of the electrode before it tries to jump to the sample to cause a breakdown.

However it is a different situation when small contact surface electrode was used. Electrodes with such pointy tips will enhance the movement of electrode to gather at the sharpest area since it is the easiest part of the electrode where electrons can transfer into another medium easily. However, the results obtained in this research showed that the small and sharp electrode yielded higher breakdown voltage. Discriminating the effects of surrounding, results of this finding could be due to the sample itself whereby the molecule structure of the material used in producing the rubber glove might contain air bubbles or other impurities that might affect the breakdown voltages[3, 7].

By referring to results of tan δ for each type of electrode, the hemisphere shape electrodes do give better value of resistance. As shown in the table above, the flat circular electrode raise only 0.3546 compared to cone shape which has 1.1053. However, the hemisphere shape electrode does give greater value of tan δ even though the average voltage breakdown is only 8.315Kv.

CONCLUSION

The test method used in this research was conducted to study the breakdown characteristic of the rubber glove in terms of its behavior when it is in contact with the electrodes/fault at energized electrical equipment according to surface area of the contact. For solid insulating material such as rubber, it is best to used oil bath vessel to conduct the test whereby this method can prevent corona at electrode edges and flashover along the surface of the glove sample[5, 7]. However this research was conducted without oil bath vessel since there proper equipment for the test is not available. Hence, the experiments were carried out with the presence of atmospheric air.

It is proven in the past that outcome of dissipation factor measurements can provide valuable information used for the determination of the general insulation condition (tan (δ))[8]. If the insulation of a solid material is free from defects like water trees, electrical trees, moisture and air pockets, the material (rubber glove) approaches the properties of a perfect capacitor. It is very similar to a parallel plate capacitor with the conductor and the neutral being the two plates separated by the insulation material.

If insulation is perfect, the loss factor (tan delta) will change a little as the applied voltage is increased. The capacitance and loss will be similar with 1 kV or 10 kV applied to the sample. If the sample has water tree contamination, thus changing the capacitive/resistive nature of the insulation, then the tan delta numbers will be higher at higher voltages.

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