In House Electrostatic Field Meter Calibration for Improved ESD Protection

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ABSTRACT

This research project presented an improved in house calibration procedure for electrostatic field meter. The proposed improved arrangement is by using copper parallel plates with the optimum separation distance of 6.01 mm between plates. The material properties test, repeatability test and reproducibility test have been conducted throughout the project. The material properties test shows that copper is the suitable material to be used as the calibration plate due to its behaviour that can withstand high voltage up to 8 kV. The repeatability test conducted shows that the arrangement produces consistent results in five cycles of measurements. As for the reproducibility test where taken into account that the arrangement has been dismantled before undergoes the reproducibility test shows that the arrangement is reproducible. This study is conducted for the improvement electrostatic discharge (ESD) protection monitoring in the production line. ESD protection can prevent from any hazard caused by ESD. Calibration of the electrostatic meter is required for the confidence in its measuring accuracy.

Keywords: Electrostatic discharge (ESD), Electromagnetic Interference (EMI), Shielding Effectiveness (SE), Electrostatic Field, Calibration.

1 Introduction

The motivation of this study is the concern on the ESD protection in the production line. Most engineering industry such as manufacturing is facing the static electricity hazard frequently. As an early step to minimize the hazard is by monitoring the static electricity presents at the workplace. The monitoring process is conducted by using a specific instrument that can measure the electrostatic field on the surface. An electrostatic field meter is used to measure the field. However, how the measurement of the meter can be confidently accepted? That is why the calibration of the electrostatic meter is required in order to gain confidence in the measurement.

The purpose of this study is to improve the in house calibration procedure of electrostatic field meter by using the copper plate as replacement to the aluminium plate. Many practical electrostatic measurements do not need to be very accurate. There is need however for proper methods of measurement and for methods of calibration which ensure reliable and comparable information. The basic equations that are fully utilized in this study are:

$$E = \frac{V}{d}\frac{Volt}{meter} \tag{1}$$

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where, E = electric field

V = voltage applied

d = distance of charge travel

$$C = \frac{Q}{V} \quad (2)$$

where, C = capacitance

Q = charge

V = potential difference

The calibration of electrostatic field meter practiced for in house generally, still has room for improvement. The main purpose of this study is to evaluate an improved outcome for the calibration of electrostatic field meter. In this paper, we will discuss on the methodology and the results obtained from this study.

By improving the in house calibration procedure of the electrostatic field meter, it also can be encompassed as one of the early steps in monitoring the Electrostatic Discharge (ESD) protection in the production line. This means, by improving the procedure, confidence in the static measurement is gained and the ESD protection step will be more efficient.

2 Methodology

The SIMCO FMX 003 Electrostatic Field Meter with 10 % accuracy was used as the subject in this study. The arrangement of the apparatus involved is referred to the international standard BS7506: Part 2: 1996 [1].

The elements that are taken into account are the applied voltage, the display reading on the electrostatic field meter as the results and the calculated electric field as the nominal value. Table 1 shows the parameters that are involved in this procedure.

Table 1: *Parameters of electrostatic field meter calibration*

Parameter	**Description**
Material of calibration plate	Copper, Aluminium
Width of the copper plates	0.15 m
Length of the copper plates	0.10 m
Thickness of the copper plate	0.001 m
Dielectric material	Air

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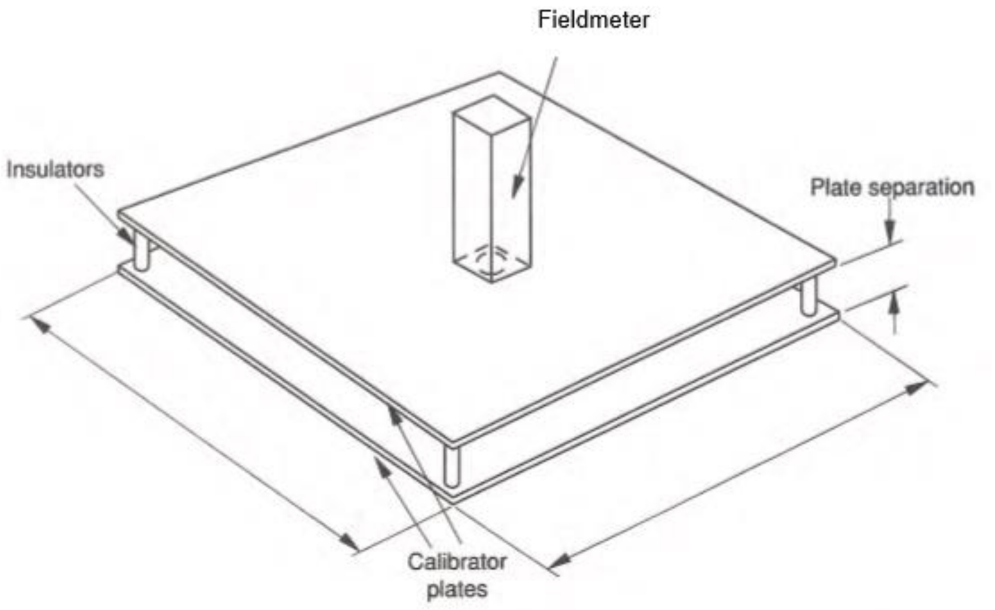

Figure 1: *Arrangement for electrostatic measurement*

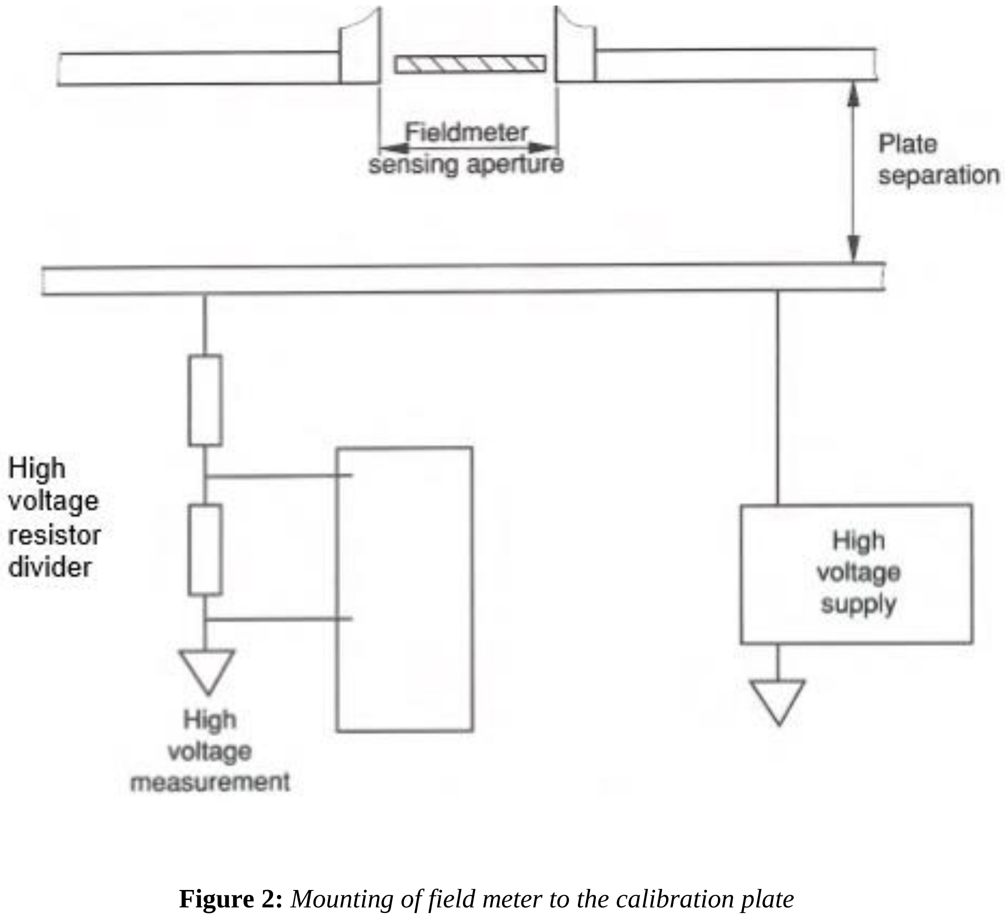

Figure 2: *Mounting of field meter to the calibration plate*

The calculated value is obtained from equation E=V/d where V is the voltage applied to the plate and d is the distance measured between the plate and the sensing aperture. The measurement unit for distance, d is depending on the model of electrostatic meter used. Most of the electrostatic meter used kV/in as the measurement unit for the electric strength measured. Therefore, to simplify the calculation, the distance measured by calliper in unit millimetre (mm) converted to inch (in).

The experiment is conducted in a few approaches. These approaches are conducted to determine the reliability of the proposed procedure. Three types of metal plates are used in this method. The former single aluminium plate, a pair of parallel plate with 6.12 mm separation distance and a pair of parallel plate with 7 mm separation distance.

Then, the parallel plate will be dismantled and re-mantled and the same measurement procedure is conducted. This is for the reproducibility test where the system is retested to determine its reliability after reproduce.

One important aspect that ought to be taken into account during the measurement is the ground clamp of the electrostatic field meter. The ground clamp must be connected to one pole of measured voltage. The arrangement of the procedure is conducted on a non-conductive pad or the ESD mat, and the electrostatic field meter is mounted on a retort stand clamp. The meter cannot be hold by hand to prevent a charging of measured electrode by a forged charge [2].

3 Results and Discussions

The electrostatic field meter and the 1.00inch distance between the plate and the meter were kept as constant parameter. Four types of tests were conducted in this study in order to achieve the objectives of this study. The material properties and plate separation distance test were conducted to determine the suitability of the calibration plate material and separation distance that can be implemented in the study. The repeatability test was conducted by taking the measurement results repeatedly with the same arrangement for 5 cycles in order to obtain the repeatability results for the measurement. The repeatability test was taken to compare the results between copper and aluminium plate. The reproducibility test was meant to determine the consistency of the measurement provided the parallel plate to be dismantled and re-mantled for each measurement cycle.

The results obtained for each test were tabulated as follows:

Table 2: *The measurement results of three different setups of apparatus*

		Copper (6.12 mm)		Copper (10.26 mm)		Aluminium	
Source Value (kV)	Calculated Value (kV/in)	Results (kV/in)	Error (%)	Results (kV/in)	Error (%)	Results (kV/in)	Error (%)
0.0	0.00	0.00	0.0	0.00	0.0	0.00	0.0
0.2	0.20	0.20	-1.0	0.26	30.0	0.20	0.0
1.0	1.00	1.00	-0.4	1.29	29.4	1.00	-0.2
3.0	3.00	3.00	0.0	4.14	38.0	2.82	-6.0
5.0	5.00	5.00	0.0	6.84	36.8	4.54	-9.2
7.0	7.00	7.00	0.0	9.62	37.4	6.02	-14.0
8.0	8.00	8.08	1.0	10.94	36.8	6.62	-17.3

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Table 3: *The results of five measuring cycles of using parallel copper plates*

Source Value (kV)	Calculated Value (kV/in)	Test 1 (kV)	Test 2 (kV)	Test 3 (kV)	Test 4 (kV)	Test 5 (kV)
0.0	0.0	0.00	0.00	0.00	0.00	0.00
0.2	0.23	0.20	0.20	0.20	0.19	0.20
1.0	1.13	0.99	1.00	0.99	1.00	1.00
3.0	3.39	3.00	3.00	3.00	3.00	3.00
4.0	4.52	4.00	4.00	4.00	4.00	4.00
5.0	5.65	5.00	5.00	5.00	5.00	5.00
7.0	7.92	7.00	7.00	7.00	7.00	7.00
8.0	9.05	8.10	8.20	7.90	8.10	8.10

Table 4: *The results of five measuring cycles of using single aluminium plate*

Source Value (kV)	Calculated Value (kV/in)	Test 1 (kV)	Test 2 (kV)	Test 3 (kV)	Test 4 (kV)	Test 5 (kV)
0.0	0.00	0.00	0.00	0.00	0.00	0.00
0.2	0.23	0.20	0.20	0.20	0.20	0.20
1.0	1.13	1.00	0.99	1.00	1.00	1.00
3.0	3.39	2.80	2.80	2.80	2.80	2.90
4.0	4.52	3.60	3.60	3.70	3.70	3.80
5.0	5.65	4.40	4.40	4.60	4.60	4.70
7.0	7.92	5.70	5.80	6.10	6.10	6.40
8.0	9.05	6.10	6.20	6.90	6.90	7.00

Table 5: *The measurement results taken after the dismantling process*

Source Value (kV)	Calculated Value (kV/in)	Results (kV/in)	Error (%)
0	0.00	0.00	0.0
0.2	0.20	0.20	-1.0
1	1.00	1.00	0.0
3	3.00	3.0	0.0
5	5.00	5.0	0.4
7	7.00	7.1	0.9
8	8.00	8.1	1.5

For this test, there are three different plates undergo the measurement. The parallel copper plates with separation distance of 6.01 mm 10.26 mm as well as a single aluminium plate. The analysis discussions of the measurement results can be referred to a tabulated measurement results presented as in Table 2. From this test, it can be analysed that copper gives better consistency on the movement of the static charge that is spread uniformly on the surface. This is because one of the properties of copper itself is it has higher conductivity value which is $5.96\ x\ 10^7$ S/m compared to aluminium which has the conductivity value of $3.77\ x\ 10^7$ S/m. Other properties are the flatness of the material. The degree of flatness of copper surface is better than aluminium where the surface is not wavy and difficult to dent [3].

The parallel plates arrangement implemented in this study acts the same behaviour as the parallel plate capacitor. The parallel plate capacitor is concerning on the capacitance obtained so that it can determine the capacity of the energy stored in the capacitor. The capacitance is influenced by the area of the plates and the separation distance of the plate. The electrostatic charge is concerned on the separation distance. As the distance between plates decrease, the capacitance increases. This is because the uniformly strong field appears at the centre of the plate. Meanwhile, the weak fringing field exists outside the plates [4].

The repeatability test findings are gathered from the measurement reading of at least three samplings and obtain the average from the samplings. In this study, the measurement is taken for five cycles or five samplings. The first measurement cycles conducted is by recording the measurement reading in increasing order. After the maximum test point reading is recorded, the voltage applied is then decreases and the reading is recorded as the second cycle measurement. The same method applies for the third until fifth measurement. This test is conducted to determine the consistency of the reading by comparing the measurement from using the parallel copper plate with separation distance of 6.01 mm and the aluminium plate as the calibration plates.

However, as the data gathered, it can be observed that the measurement on the aluminium plate might be influenced by the method of the voltage being applied to the surface of the plate. This is the effect of the charge accumulation on the surface. The measurement obtained by using the aluminium plate is inconsistent compared to parallel copper plates where the measurement was consistent throughout the whole process.

The reproducibility test is conducted as one of the methods to determine the reliability of the proposed in house calibration procedure of electrostatic meter. The procedure is conducted by dismantling the parallel copper plates. The need of this reproducibility test is to provide more consistency from the perspective of stable electrostatic measurement repeatability [5].

After the dismantling process, the plates are left in a controlled room of 22 ºC and 50% RH for one hour and then the plates were re-mantled. Next, the measurement cycle was repeated. From the analysed results, the percentage error is less than 2%. The pattern of the measurement error is almost the same as before the parallel plates were dismantled. This event proves that the behaviour of the copper plates remains the same. The response or behaviour of the parallel copper plates is not influenced by the temperature and humidity.

4 Conclusion

The most reliable system to be implemented for the improvement of in house electrostatic field meter calibration procedure is the parallel copper plates with 6.01 mm separation distance. The plates also showed convincing results on its reliability as well as consistent measurement reading in particular arrangement conducted throughout the study. Therefore, from the test conducted, shown that the measurement of electrostatic charge using copper parallel plates of 6.01 mm optimum separation distance, is repeatable and reproducible. Further study can be suggested to overcome the issue related to the distance between the electrostatic field meter and the calibration plates as it plays an important role in the measurement. Therefore, the gap must be precise. To make the arrangement easier, a gap gauge can be fabricated and utilize so that an accurate measurement can be obtained.

5 Declarations

5.1 Competing Interests

There is no conflict of interest.

5.2 Publisher's Note

AIJR remains neutral with regard to jurisdiction claims in published maps and institutional affiliations.

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