

Conductivity Measurements and Interpretations regarding Antistatic Materials

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Abstract - In this work, measurements are given of ohmic resistances in samples of fitted anti-static flooring. The measurement procedures were based on the relevant regulations DIN 51953 and DIN 53482. The measurement values that are shown concern various types of aged anti-static flooring that is commonly found and used in intensive care facilities such as operating theatres, extra care treatment rooms, areas with Computer Tomography systems, etc. Furthermore it presents measurements of new types of anti-static flooring for reasons of comparison. All results are presented in table form and are analysed in detail. The results of all the measurements of this exercise taken into consideration, an attempt is also made to interpret the phenomena that lead to the reduction of conductivity in these materials, and subsequently how these phenomena can be prevented.

I. Introduction

Electro Static Discharge (ESD) is the instantly free movement of electric charge from one point to another without the existence (assistance) of an external source [1, 2].

The discharges of this category are usually associated with surface charges of low conductivity materials and the charge production mechanisms are distinguished by two basic methods [2]: the physical method (triboelectric and induction charging) and the laboratory method. The latter includes the categories below [1-6]:

- ion and electron beam charging,
- spray charging,
- field emission charging,
- photoelectric charging, and
- impact ionization charging

The production of the above electrical carriers is facilitated by the increase of temperature while the increase of relative humidity results in the exponential reduction of discharge voltage [1, 2, 7]. Humans are a source of static electricity [1, 2, 8, 9]. This is due to the appearance of bioelectric phenomena in the body, which are subjected to continuous change of chemical energy into electrical during the metabolism of cells [2]. Furthermore because humans have a capacity and usually a great ohms resistance, they are electro statically charged by frequent low currents (partial μA type) which may stem from leakages from electrical appliances as well as from inductance [1, 2]. A simple circuit model of the human body consists of a resistor in series with a capacitor. The resistance of the human body is the sum of its core resistance of about 500Ω plus the skin resistance with values between $1 \text{ K}\Omega$ and $100 \text{ K}\Omega$ depending on the skin's physiology and has a significant dependence on the humidity. The capacity ranges from 100 pF to 300 pF [2, 8].

Experimental results indicate that the level of the energy released from an electrostatic discharge event ranges from a few to several hundred millijoules depending on capacity and voltage [2]. The general waveform obtained during an electrostatic discharge is a double exponential impulse with rise time from $0,5$ to 20 nanoseconds, virtual time almost ten times longer and peak voltage value of the positive or negative pulse between $1,5$ to 35 KV and rarely 40 KV [1, 2, 8, 10].

Some of the most important problems brought about by electrostatic discharges are [1, 2]:

- The danger of explosion or ignition when they coexist with flammable vapor (e.g. the oxidant medical gases where intensive care facilities exist, etc).
- Soft failures which are intermittent and result in functional disturbances
- Hard failures which result in permanent damage of the electronic devices.

The protection from Electro Static Discharge demands methods that aim to remove all free electric charges. The most important methods for protection are [1, 2]:

- Fitting of anti-static flooring,
- Good earthing of electric appliances,
- Use of anti-static materials (shoes, bedding, clothing, etc),
- Storage of flammable gases and liquids in electrical conductive containers, and
- Installation of a special air conditioning system.

In this work, measurements are given of ohmic resistances in samples of fitted anti-static flooring. The measurement procedures were based on the relevant regulations DIN 51953 and DIN 53482. The measurement values that are shown concern various types of aged anti-static flooring that is commonly found and used in intensive care facilities such as operating theatres, extra care treatment rooms, areas with Computer Tomography systems, etc. Furthermore it presents measurements of new types of anti-static flooring for reasons of comparison.

II. Quality control and the use of anti-static materials

The quality control of anti-static materials is undertaken through the measurement of their ohmic resistance (R_A) [1, 2]. In practice, with several methods according to the international specifications, this becomes.

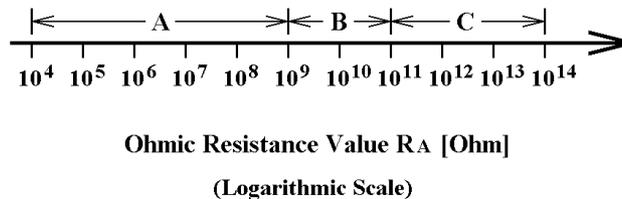


Figure 1. Simplified arrangement based on the ohmic resistance value (R_A) of the material in relation to their possibility in eliminating the electrostatic carriers and their electrical properties. (These values of the R_A are in Ohm and the order of this scale increases logarithmically).

A: The range of anti static materials. These materials eliminate the electrostatic carriers because $10^4 \Omega < R_A < 10^9 \Omega$ (semiconductor's range). B: These materials have limited possibilities in eliminating the electrostatic carriers ($10^9 \Omega < R_A < 10^{11} \Omega$). C: Insulating materials ($10^{11} \Omega < R_A < 10^{14} \Omega$). The insulating materials do not eliminate the electrostatic carriers and they are electrostatically charged.

A simplified arrangement of those materials (based on their ohmic resistance value) in relation to their possibility in eliminating the electrostatic carriers and their electrical properties, is given in figure 1. In this figure the values of the R_A are in Ohm and the order of this scale increases logarithmically. In the same figure the values are also given when the order of the ohmic resistance value R_A of the materials is greater than $10^9 \Omega$ ($R_A > 10^9 \Omega$). These materials act as insulators. In general, insulating materials do not eliminate the electrostatic carriers. This means that insulating materials can be electrostatically charged and are inappropriate for use in areas where they can be electrically charged. This procedure is due to the charging phenomenon or to the inducing phenomenon. These phenomena can be obtained in of intensive care treatment areas of the hospitals [1, 2].

In the beginning, the sub - floor (screed) must be free of moisture, if necessary by means of a damp layer and adequately firm and robust; it must not crack under the castors of heavy, mobile units. Figure 2 shows a simplified diagram of the network of conductive copper strips (10 x 0.1 mm) which should be soldered at the overlapping ends at both the longitudinal and transverse wall before the covering is laid.

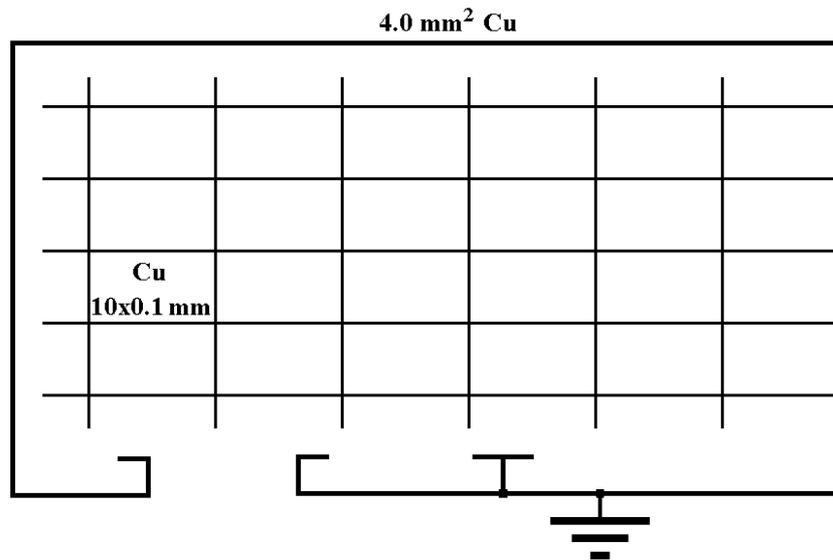


Figure 2. A simplified diagram of the network of conductive copper strips (10x0.1 mm) which should be soldered at the overlapping ends at both the longitudinal and transverse wall before the covering is laid.

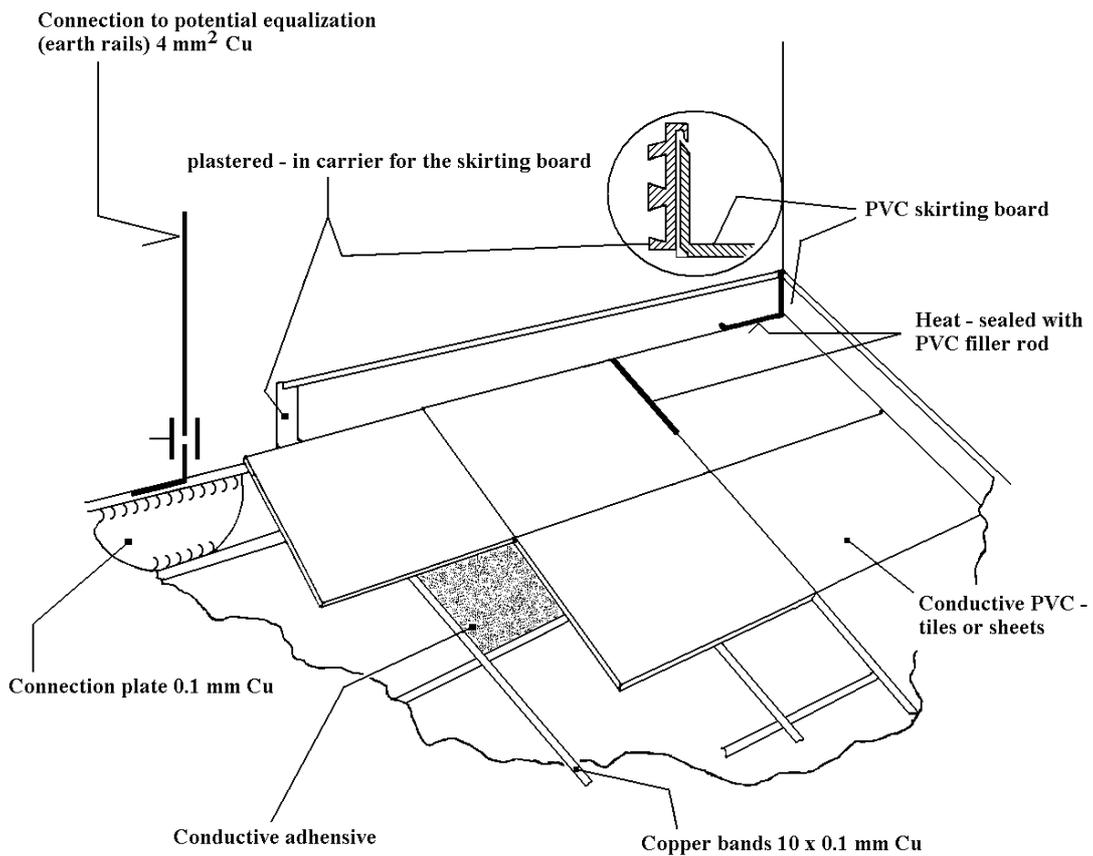


Figure 3. A representative example for the production of the conductive floor and the connection with the conductive PVC – tiles or sheets.

The conductive net of copper strips according to VDE 0107 /3.68 must be included in the additional electrical protective measures by connection to the PE (potential equalization) at one point, in the case of large rooms ($\geq 40 \text{ m}^2$) at two points in opposite corners, but with a common conductor ($\geq 4 \text{ mm}^2 \text{ Cu}$). It must not be grounded or connected in any way to the lightning protective system. At the connection point it is necessary to solder a semi - circular shaped copper sheet of about $300 \text{ mm } \Phi$ and 0.1 mm thickness to the conductive network; at least, a 50 mm length of the potential equalization lead should be carefully soldered to the connection plate, otherwise an adequate mechanical strength cannot be guaranteed at the connection point. In figure 3, an example for the production of a conductive floor and the connection with the conductive PVC – tiles or sheets, is given.

III. The Experimental Arrangement, the Measuring Procedure and the Measurement Results.

Figure 4 shows a simplified circuit of the method that was used for the measurement of resistance in samples for various antistatic materials. This includes a commercial ohmmeter, the anode electrode, a piece of blotting paper, the earth electrode, the specimen of the antistatic material and a weight of 10 N .

The normal commercial ohmmeter measuring up to $10^3 \Omega$ and using 100 volts direct current as the measuring output. Warming cupboard with air replacement according to DIN 50011, measuring electrode of 50 mm diameter (the area of this electrode is 20 mm^2), the applied pressure should be about 10 N , blotting paper, 50 mm diameter (like a damp filter paper or a moist, thin cotton cloth is also permissible).

In the case of floor coverings laid from rolls, two square specimens, with edges at least 200 mm long, are to be taken. For tiled material, two tiles are to be taken from the delivery. The specimens should be large enough to allow 3 tests to be made on each.

Adhering wax and dirt particles are to be thoroughly cleaned off the specimens with alcohol or another agent which does not attach the specimens.

After cleaning, a contact electrode is applied over a large area of the underside of each specimen, using stabilized colloidal aqueous suspensions of graphite.

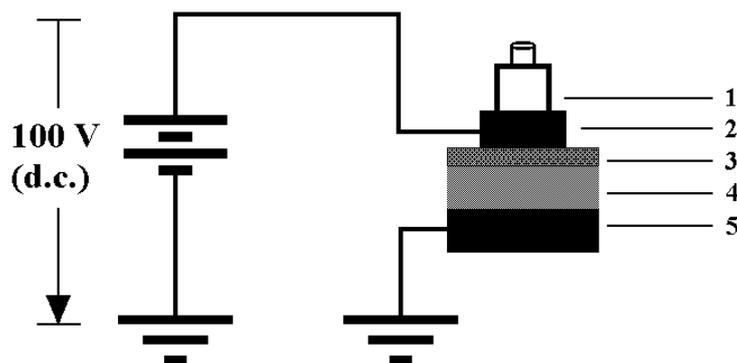


Figure 4. Simplified circuit of the method that was used for the measurement of resistance in samples for various antistatic materials according to specifications DIN 51953 and to DIN 53482. (This circuit corresponds to the case where the floor coverings are laid from rolls).

- 1: Weight 1 kp ($1 \text{ kp} \approx 10 \text{ N}$).
- 2: Measuring electrode of 50 mm diameter with a area of the 20 mm^2 (The potential of the positive electrode is $+100 \text{ V d.c.}$ in comparison to the earth potential).
- 3: Intermediate layer. Blotting paper with a diameter of 50 mm .
- 4: Anti static material specimen (square specimens, with edges at least 200 mm long).
- 5: Negative electrode of 75 mm diameter with a area of the 45 mm^2 (This electrode connects at the potential equalization of the structure earth).



Figure 5. Analogical device of the HEWLETT-PACKARD Corporation, which was used for the measurements of antistatic materials ohmic resistance values (according to DIN 51953 or DIN 53482 specifications).

The specimens are then dried for 96 hours in a warm cupboard at $(40 \pm 2) ^\circ\text{C}$, with replacement of the air. The specimens are to be laid out in the warm cupboard in such a way as to enable free air flow to all sides. Measuring takes place after cooling to $23 ^\circ\text{C}$ over a drying agent.

In figure 5, the device which was used for the measurements of the antistatic materials ohmic resistance value (according to DIN 51953 and DIN 53482 specifications), is shown. This device was constructed by HEWLETT-PACKARD for this purpose. This analogical ohmmeter can measure up to the range of $10^3 \Omega$ and its maximum division is in the order of $10^{14} \Omega$ (High Resistance Meter), using 100 Volts direct current as the measuring output voltage.

The results of the measurements obtained permit assessment of the ability of floor coverings to conduct electrical charges away to earth. The tests can be conducted on specimens or on the laid floor covering, where the effect of the conductivity of the adhesive and of the underlying layers is to be taken into account. In the case of textile floor coverings, the electrical resistances are tested according to DIN 54345 Part 1. For other application ranges, the appropriate provisions of VDE 0100 "Regulations for the Installation of Power Systems with Rated Voltages up to 1000 Volts" are to be applied.

The results of the measurements are presented in the table below which also include measurements of new anti-static flooring for reasons of comparison. The results show that an important amount of flooring, maintained at a satisfactory level keep its resistance despite ageing. However, there were instances of some flooring, whose conductivity had been decreased and did not correspond to the specification requirements, and thus cannot be characterized as antistatic.

TABLE

Serial Number of anti static flooring specimens	At date of laying	After 1 year	After 2 years	After 3 years	After 4 years	After 5 or more years
	Ohmic Resistance value R_A [Ohm]					
Number 1	$\leq 10^6 \Omega$	$\leq 10^8$				$\approx 10^9$
Number 2	$\leq 10^6 \Omega$	$\leq 10^8$				$\approx 10^9$
Number 3	$\leq 10^8 \Omega$	$\approx 10^8$		$\approx 10^9$	$\approx 10^{10}$	$\approx 10^{11}$
Number 4	$= 2,3 \times 10^9 \Omega$	$\approx 10^9$		$\approx 10^{10}$		$1,3 \times 10^{11}$
Number 5	$= 2,3 \times 10^9 \Omega$		$\approx 10^{10}$			$2,2 \times 10^{11}$

IV. Conclusions

Testing of antistatic materials can be undertaken through the measurement of their resistance with methods and procedures that are determined in the specifications and carried out in the relative regulations. For all the above, the resistance value is given in samples for antistatic flooring. The measurement procedures are based on the relevant regulations DIN 51953 and DIN 53482.

The measurement values that are shown concern various types of aged anti-static flooring that is commonly found and used in intensive care facilities such as operating theatres, intensive care treatment rooms, areas with Computer Tomography systems, etc.

From all the above measurements the following conclusion can be made: the resistance of anti-static flooring is increased with time. The measurements show that an important amount of flooring, maintained at a satisfactory level keeps its resistance despite ageing. However, there were instances of some flooring, whose conductivity had been decreased and did not correspond to the specification requirements, and thus cannot be characterized as antistatic.

A possible reason for the ageing of the above anti-static system could be the oxidation of the copper bands (with dimensions of 10 x 0.1 mm). A second possible reason for the ageing of this anti-static material could be the timing mechanical ageing of the conductive PVC tiles – sheets, which is attributed to the polymerization of these sheets.

The results of all the measurements of this exercise taken into consideration, an attempt is also made to interpret the phenomena that lead to the reduction of conductivity in these materials, and subsequently how these phenomena can be prevented.

From the above, we came to the conclusion that in Hospitals inspection of anti-static flooring (and possibly of all other anti-static materials) should be carried out systematically to ascertain their suitability and to prevent undesirable consequences. In all these work areas it is recommended that inspections are made at time intervals of approximately two years.

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