ELECTROSTATICS COMFORT IN BUILDINGS AND OFFICES: SOME EXPERIENCES AND BASIC RULES

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Abstract

Electrostatic charges may cause several damages to electronic devices, sensible products or processes. They may also lead to electric discharges which represent a hazard for explosive atmospheres or may cause serious problems in equipment in hospitals. For these well-known situations there are standards that give rules and solutions to users and designers. However, there is still a large field of possible electrostatic problems which cannot be classified into damages or dangers but that represent rather a problem of discomfort to users. Some examples are electrostatic discharges in homes, offices, shops, supermarkets, public areas or public car parks. The general solutions proposed in the standards for electrostatic charges in industrial environments, may not be applicable or cost-effective for these situations. These cases represent an original technical problem aimed at solving the troubles caused by electrostatic charges to users. Solutions may be inexpensive, definitive (i.e. without maintenance or requiring very long periods for maintenance) and, in some situations, they may reduce at a maximum their visual impact for esthetical reasons (e.g. the use of coating with conductive black painting are seldom acceptable).

This paper will describe some representative examples of electrostatic discomfort in non-standardized environments, gathered after 15 years of experience. Some practical solutions will be proposed.

Keywords: Electrostatic charge, comfort, triboelectricity, standards.

1. Introduction.

The Cambridge dictionary [1] defines comfort as "*a pleasant feeling of being relaxed and free from pain*". Comfort is a psychological and physiological concept that cannot be measured and depends on the individual perception. However, from a technical point of view, comfort has been studied for indoor thermal comfort perception and some long-term discomfort indices have been defined (see [2], chapter 1). There are also studies in the field of textile engineering defining comfort [3] which make some reference to the presence of electrostatic charge [3][4][5]. In the field of buildings, there are some examples of current research of electrostatic charge presence related to illness in users or productivity [6].

The electrostatic comfort, as we define it, is not related to health, hazards or accidents. Maybe this is the reason why, at present, it has not been developed as a relevant topic. However, in our laboratory, we receive several enquiries every year from users that are affected by electrostatic discharges and discomfort in houses, offices, shops and public areas. It is generally treated as a minor bother to users but it can be easily more than this. It is very repetitive, very often it generates a perceptible pain and it can happen in new houses where owners have made a large investment. This may cause psychological fatigue and a continuous stress level. From a commercial point of view, electrostatic discharges in shops or commercial areas can give a bad impression to customers. Electrostatic comfort may seem a minor concept if not addressed as a health or hazard issue, but it is a very common problem that deserves attention from a technical point of view. Besides, no standard covers exactly this field and consultants and technicians, when facing electrostatic comfort problems, have to apply standards coming from the field of electronics [7] or ATEX environments [8] which require very strict rules to be applied. It is also very remarkable, that, to our knowledge, building codes do not pay attention to electrostatic problems in houses at the design phase (see for example, [9][10]). Requirements for electrostatic comfort are much less strict and solutions need to be less expensive, easily applicable and definitive (i.e. without maintenance or requiring very long periods for maintenance). In some situations, they may reduce at a maximum their visual impact for esthetical reasons (e.g. the use of coating with conductive black painting are seldom acceptable). It is thus necessary to define some basic rules and critical values to help in solving and preventing electrostatic discomfort situations. In this paper, we will discuss the concept and limits of electrostatic comfort, describe some cases we have faced in the last 15 years in the Industrial Electrostatics laboratory of the Instituto Tecnológico de la Energía (ITE) and propose some solutions. As for the future, a standard or technical recommendation for electrostatic comfort should be advisable.

2. Current state of standards

Static electricity is taken into consideration in many international standards [11]. We will discuss some of them. The IEC 61340 series covers the measurement methods, protection methods and application cases for avoiding electrostatic charging, hazards and damages, mainly in ESD Protected Areas (EPA). Requirements are very strict in many cases. For example, in electronic equipment, electrostatic voltages have to be kept, at least, below 100V. But it has been found that magnetoresistive heads and Radio Frequency FET transistor may suffer damages from 10 to 100V [12].

In the Technical Recommendation TS 60079-32-1 [8], it is considered safe to keep electrostatic potentials below 100V by means of grounding. Besides, grounding is recommended from a practical point of view to be done through a resistive path of 1MΩ as a maximum and the discharge time of any item, included persons, should be less than 0,1s. Additionally, insulating materials surfaces and sizes as well as possible capacities to ground are limited according to the ATEX zone.

Finally, ANSI/ESD S20.20 [13] also requires 100V as the maximum voltage for personnel grounding and a maximum of $10^9\Omega$ for the grounding path (footwear and floor) of the personnel.

These three standards give information and values of electrostatic potentials for safety reasons, but threshold levels for electrostatic comfort are not under consideration.

Electrostatic comfort is a matter of electrostatic discharges perception. Some indications are given by the IEC/TS 60479-2:2007 [14] where threshold for perception and pain is shown for different waveforms of applied voltages. It has to be taken into account that this Technical Specification is aimed at the effect of current on human beings and livestock due to external elements such as AC power supplies. As stated by the document, experimental data has been obtained on animals and from medical observations in humans after accidents. Only some few short duration current tests have been carried out on humans. The main objective of the Technical Specification is to establish dangerous limits for humans, in particular for ventricular fibrillation. A paragraph is devoted to discharges from charged capacitors as a source of hazards. In particular, there is a detailed figure showing the perception and pain thresholds for a discharge from a charged capacitor to a human body (see a representation in figure 1). From an electrostatic comfort point of view, the situation is generally the opposite: the human body, commonly represented as a charged capacitor of 100-150pF, suddenly discharges in a grounded conductive element (discharge to ground) or a floating conductive element (discharge to another capacitor). However, the information shown in figure 1 can be taken as a reference to estimate the perception threshold. In the end, it is a discharge from a capacitor which crosses the human body irrespective of the direction of the charge transfer. We consider that the situation is the same if a 100pF capacitor discharges in a human body or a human charged body (represented by a 100pF capacitor) discharges in a grounded conductive objet. Unfortunately, the information given in the figure of IEC/TS 60479-2 is limited to 1000V. The limit points that are given in [14] for perception of electrostatic discharge are roughly discharges coming from 330pF and 1nF capacitors both charged at 1000V (indicated in figure 1 as points A and B respectively). These capacities are higher than the standard representation of human capacity, thus, to estimate the electrostatic discharge perception threshold from this figure; we consider that the effect will be similar if the energy is the same. Equaling the energy of these two points to the energy of a 100pF capacitor representing the human body capacity; we obtain 1816 V and 3162 V as the lower and upper limits of electrostatic discharge perception. Extrapolation of the diagram represented in figure 1 to higher voltages for 100pF gives higher values (4000 V to 10000 V) which are less in agreement with common experience in electrostatic measurements. The limits of the electrostatic discharge energy for perception are roughly 0.15 to 0.5 mJ and lower limit for the pain threshold is 5 mJ approximately.

As a complement, it can be noted that the standard CSN EN 1815:1997 indicates a perception level of 3000 V for a majority of people.

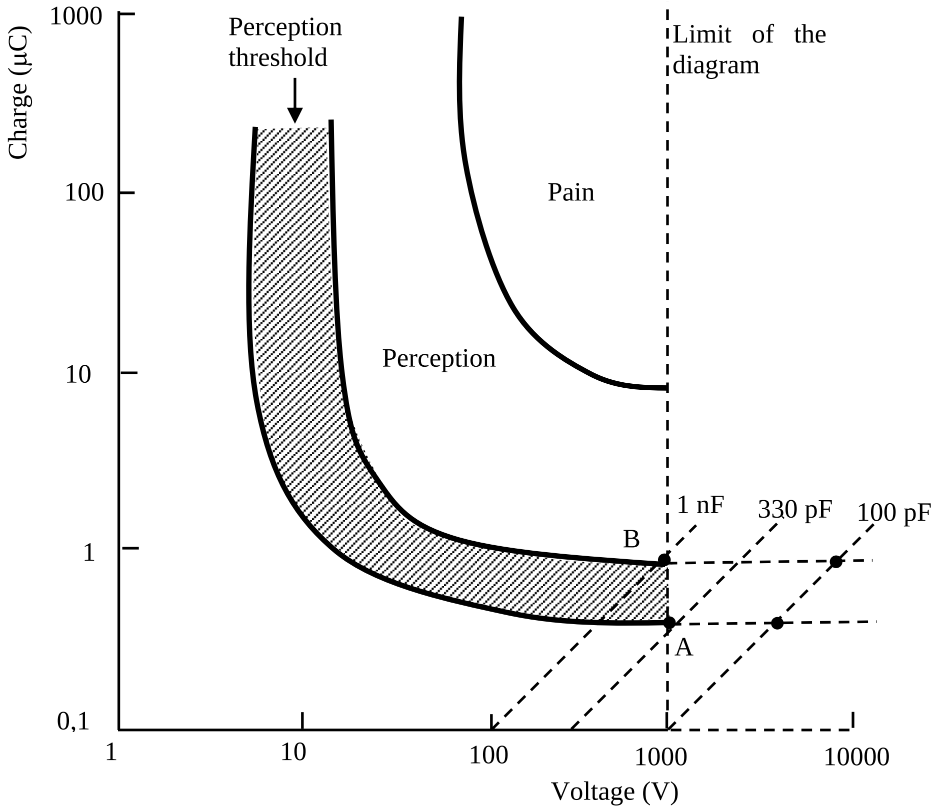

Figure 1. Approximation of perception thresholds elaborated from [14]. Represented values are not exact, for more information see [14].

However, experimental work on the perception level should be carried out since probably the ambient conditions have an effect not only on voltage charging levels but also on the nature of the discharge in the air. For example, if someone is enough electrostatically charged, when approaching the index finger to a non-metallic conductive wall an electrostatic discharge can be felt, sometimes inducing pain depending on the electrostatic potential, the discharge energy etc. If the hand palm is approached parallel to the wall instead of the index finger, multiple small painless discharges can be heard (figure 2). Of course, this is related to the current density in the skin but also to the dynamics of the discharge. When approaching the hand palm the discharge does not make the transition to a spark discharge with higher current densities.

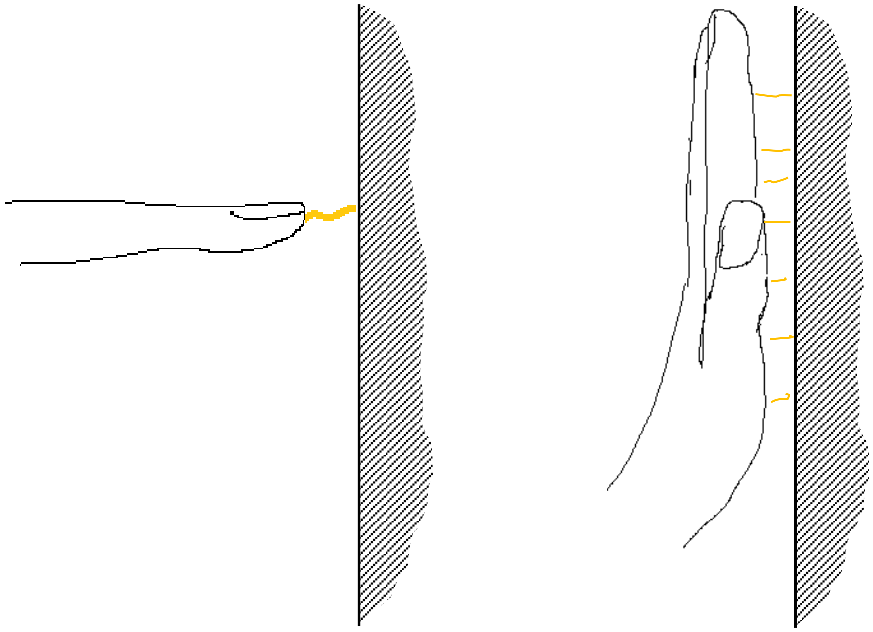

Figure 2. Comparison of the discharge from the index finger or the palm hand to a non-metallic conductive wall.

IEC/TS 60479-2 [14] indicates, for discharges from a capacitor, that specific energy for pain threshold is about 50 to 100 × 10^{-6} A^2×s for large contact areas through the legs. It is difficult to deduce current values for an equivalent electrostatic discharge but, taking as a reference the human body model (HBM) of standard IEC 61000-4-2:2008 [15], an electrostatic discharge can be roughly described as an impulse of about 100ns with amplitude A_{max} (figure 3). Then the current amplitude corresponding to the pain threshold obtained from the specific energy for pain threshold can be estimated about 39 to 55 A by integration of the square of the approximated current curve of figure 3. As a reference, the peak current for an electrostatic discharge generated from a 150 pF capacitor charged at 4kV corresponds to 15A according to [15]. Unfortunately there is no reference to a specific energy for perception threshold in [14].

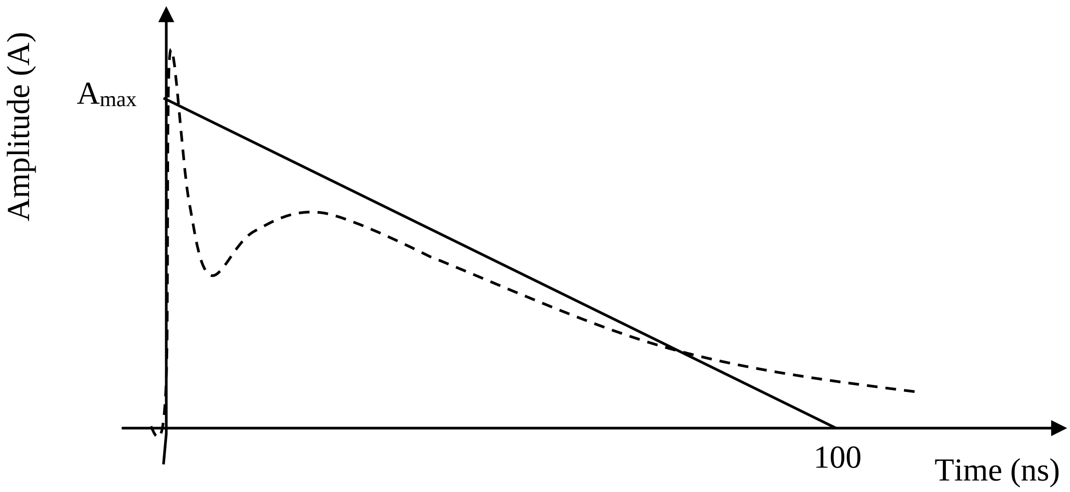

Figure 3. Approximation of an electrostatic discharge impulse taken from IEC 61000-4-2:2008 (dashed line).

As far as the standards do not address the electrostatic comfort problems, we present now some typical cases from which we can deduce some general rules and learn certain lessons.

3. Practical cases.

There are two main origins of electrostatic charges in homes and offices: furniture and floors. Of course, the combination of both is also important. But, from an electrostatic point of view, in many cases it is enough to solve one of them. In some large areas, such as commercial malls, the effect of floor as a generator of electrostatic charge on people walking can be noticeable because users can walk relatively long distances before discharging themselves. But in homes and offices, floor may play a more important role in preventing electrostatic charges dissipation than in generating electrostatic charges, although this cannot be excluded.

However, the experience shows that the most important cause for electrostatic generation is the domestic furniture: chairs, armchairs, beds, etc. Of course, electrostatic charge generation depends on ambient conditions and air conditioning systems may also worsen the situation when reducing ambient humidity.

3.1. Domestic furnitures.

The potential of people standing up from chairs or armchairs has been measured in several situations by means of a hand held metallic electrode connected to a JCI 148 voltmeter in combination with a field mill JCI 140F ensuring very little disturbance of the electrostatic potential to be measured (see [16] for electrostatic potential measurement recommendation of low capacity to ground object or [17] and [18] for measurement setups). It is very common to measure potentials from some hundreds volts to more than 12kV. A question about how necessary is the use of grounded conductive chairs to ensure electrostatic comfort can be asked. The experience shows that it is enough to obtain a low triboelectric charge generation. For example, in some cases, chairs made of leather produced small electrostatic charge when compared to synthetic tissues or plastic materials for the same users. This is also very clear in figure 4 where it is shown the electrostatic potential of a person standing up from a chair with synthetic tissue. The electrostatic potential was measured by means of a hand held metallic electrode connected to a JCI 148 voltmeter in combination with a field mill JCI 140F. The person was initially discharged when seated by touching a grounding point. As it can be seen, the potential reached values over 1000V on users. A conductive antistatic surface was used to cover the chair without grounding it, and the electrostatic potential was dramatically reduced (figure 4). It can be observed that short (< 2 s) transient potentials close to -200V were produced, probably due to charge generation and neutralization during the process of standing up from the chair. In this modified situation, there are 3 surfaces rubbing each other: the user dress, the antistatic surface and the synthetic surface of the chair. This complex interaction can lead to charge generation but the conductivity of the new covering probably improves non perceptible microdischarges during tissue separation. This may not be appropriate for industrial situations but in homes and offices it is enough to avoid electrostatic discomfort. Grounding of the conductive surface of an antistatic chair by a cable may lead to other discomfort situations due to the presence of the cable and the limitation of the chair movement.

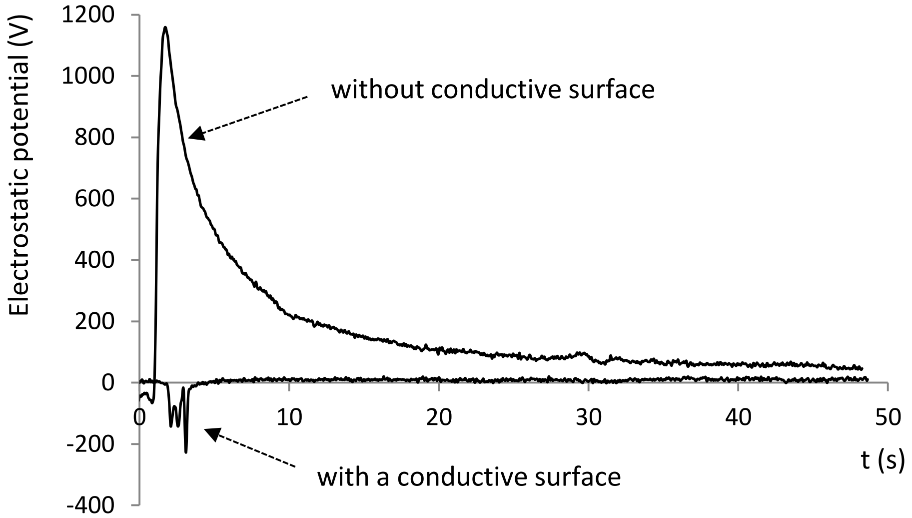

Figure 4. Effect of a conductive surface on a chair where electrostatic charge is generated.

In another case, electrostatic potentials were measured with the same setup in an office before and after replacing chairs by antistatic chairs. Antistatic chairs were not grounded. In this case, nearly 90% of the working places did not present high electrostatic potentials (< 3 kV) except one case where it was found that a heater was very close blowing dry air to the worker directly. This reduced locally humidity and dried all the tissues and skin of the worker. Potentials up to 6kV were found. It was recommended to move the heater to another place. Increasing of air humidity was also recommended, but this was more complicated to be done and, at the moment of these measurements, humidity was close to 30% at 21ºC instead of the recommended 50% humidity.

In this case, resistance to ground of the chairs was also measured with a conductive electrode according to IEC 61340-2-3 [20] on the chair and the chair placed on a conductive metallic surface. The resistance to ground was measured in several chairs before replacing them by antistatic ones (figure 5). The electrostatic potential generated when standing up was also measured as described above. The same person performed all these tests. It cannot be found a direct correlation between both variables. The lowest values of generated electrostatic potential corresponded to leather chairs.

Thus, from an electrostatic comfort point of view, it is more important to limit triboelectric charge generation in chairs than ensuring a conductive path to ground. Grounding of the chairs can be done and this will improve results, but it may cause usability problems to users.

In one different case in a house, the use of a cotton sheet covering a large armchair reduced the electrostatic potential of a person, measured as in the other examples, from 18kV to 2.5kV under low relative humidity conditions (33%).

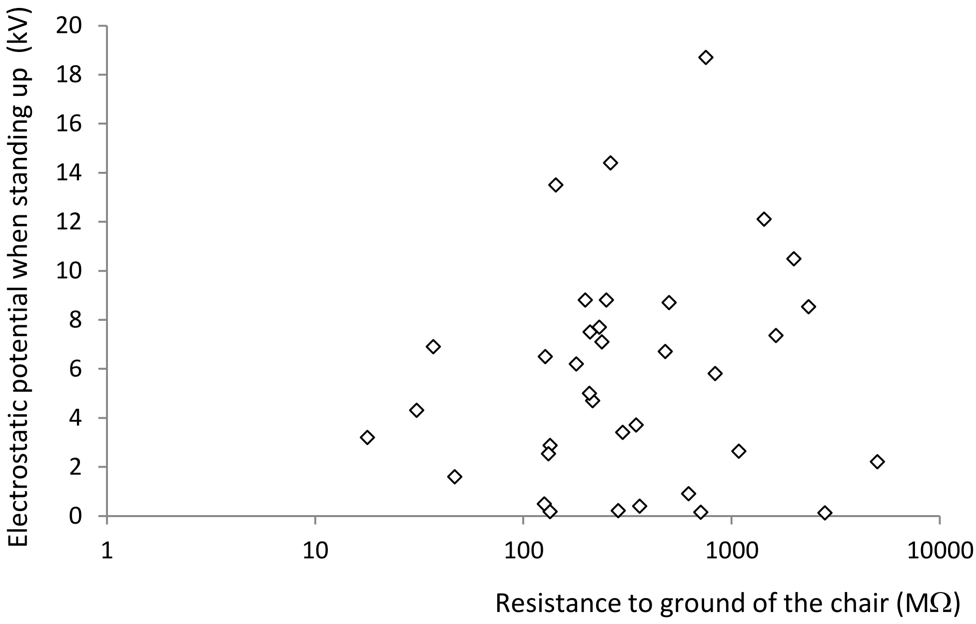

Figure 5. Electrostatic potential generated by a person when standing up from different chairs related to the resistance to ground of the chairs.

3.2. Floors

The problem with floors is twofold: (1) electrostatic charges can be generated when walking and (2) an insulating floor can avoid charge dissipation on charged people, normally after standing up from sitting or walking. In figure 6, both phenomena can be observed: the electrostatic potential of a person was measured by means of a hand held metallic electrode connected to a JCI 148 voltmeter in combination with a field mill JCI 140F. The person was initially discharged by touching a grounded object and then started walking with rubber sole shoes on a non-antistatic floor (laminated floor). After 20 s, the person stopped walking and the potential decay was recorded. A potential of -1.5 kV was reached when walking with a dissipation time of more than 10 s when stopping. In some cases, the time for charge dissipation maybe of some minutes letting time enough for the user to touch a metallic grounded or ungrounded part and generate an electrostatic discharge.

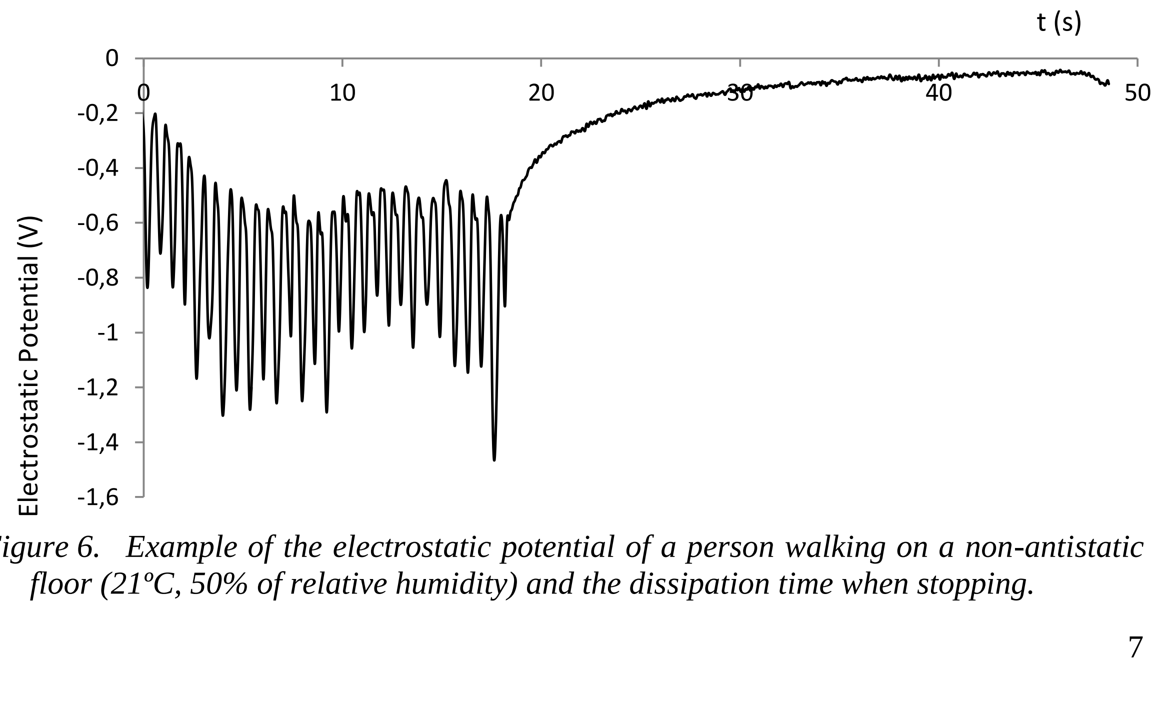

Figure 6. Example of the electrostatic potential of a person walking on a non-antistatic floor (21ºC, 50% of relative humidity) and the dissipation time when stopping.

It is well known that the effect of floors has to be evaluated in combination with footwear. This is also true for electrostatic comfort. Large differences can be observed between people with different shoes walking on the same floor. From an electrostatic comfort point of view, there are some important limitations to solve problems generated by an inappropriate floor choice:

- normally no action can be made on the shoes used by people and the use of rubber or EVA soles in shoes is growing
- the problem with floors is detected once they have been installed
- conductive paintings are normally not acceptable because of their black or grey color
- changing the floor of houses is very difficult due to economic, esthetic or practical reasons; this may be possible in offices but normally it is considered an expensive solution for a minor problem (discomfort)
- conductive additives for floors may be a solution but require regular maintenance, are more expensive than common products and may be difficult to find in stores.

The situation for carpet floors may be worst since there are no easy solutions to modify them. Solutions based on the use of dissipative carpet floors can be implemented but requires replacement of the existing non-antistatic carpet floor. Another possibility is the use of antistatic sprays for carpets but they also need periodic maintenance (some months) and extra cost for particular users.

A new element in houses that can generate electrostatic charge is the artificial grass in terraces and balconies. In one case, walking on artificial grass on a balcony lead to up to 9 kV when the artificial grass was directly laid on the non-conductive floor. The use of a conductive carpet below the artificial grass reduced it to 1.5 kV. There exist antistatic artificial grasses that reduce the static charge to a minimum. If the affected surface is not very large, replacement can be envisaged.

From our experience, as a general rule, the maximum value of resistance to ground of the floor can be established at 1 GΩ, like in industrial standards. But this value, alone, does not warrantee electrostatic comfort since the situations can be very different from one case to another (e.g. the amount of charge generated by furniture, the kind of shoes of the users, the relative humidity, the walking distances, etc.).

Very often, no action is taken by users to improve floors. Probably, the simplest solution for all kind of floors is to increase air humidity in order to reduce charge generation. Another possibility is to cover the floor with an antistatic laminate floor which may be less expensive than floor replacement and offers different esthetic possibilities.

In some few cases, some actions had been taken before the installation of the floor in order to improve electrostatic dissipation of charges of non-antistatic floors. The installation of a conductive mesh below a floor can reduce, not eliminate, the dissipation time and the maximum value of the generated charge. But it is difficult to predict the final result. This example of anticipated actions is not a common situation since the concept of electrostatic comfort is not well known and the standards for building, to our knowledge, do not give rules to prevent it [9][10], not even mention it.

3.3. Some particular cases

Electrostatic comfort can appear in very different situations. One representative case is the electrostatic discharges received from supermarket trolleys.

Some measurements were carried out with a special arrangement based on a field mill JCI 140F placed in front of a flat metallic plate attached to the trolley. That allows long movements of the trolley inside the supermarket. Calibration of the measurement system was done with a high voltage generator connected to the trolley. Depending of the type of floor, the trolley could reach potentials as high as 3.5kV at 45% relative humidity producing discharges to users or transferring charge to users.

Nowadays, there is a trend towards replacing metallic trolleys by plastic structures to avoid user discomfort.

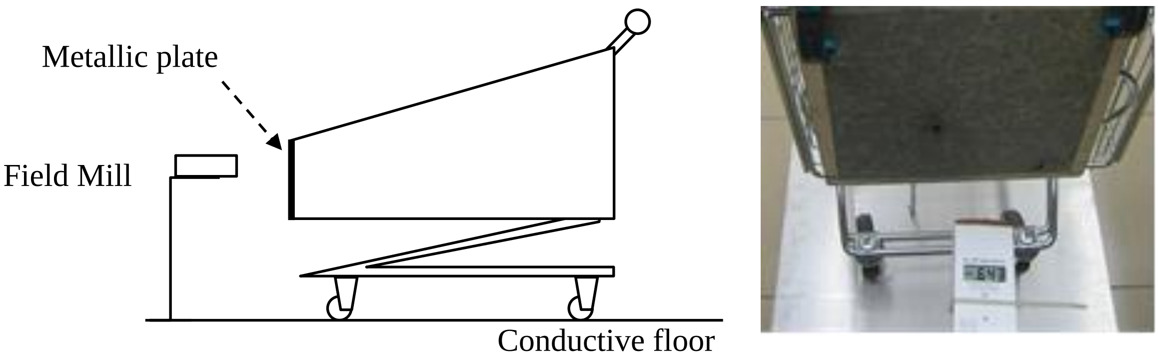

Figure 7. Electrostatic potentials measurement in supermarket trolleys.

Another remarkable case was found in a commercial parking were customers received electrostatic discharges when inserting the validated parking ticket in the checking machine before leaving the parking. In this case, the car was charged when circulating inside the parking. The potential was measured again with a metallic electrode stuck to the car and connected to a JCI 148 Electrostatic voltmeter coupled to a JCI 140 field mill. The measuring system was connected to the car in such a way that it could run over 5 m before the cable was disconnected (figure 8). Using a grounded aluminum band laid on the floor close to the checking machine was enough to cancel the electrostatic potential of the car since the tyres are conductive. It was clearly found that the absolute value of the electrostatic potential of the car increased very fast but was also immediately discharged when crossing the metallic band. The first wheel fully discharged the car, probably because of its connection to the engine, whereas the rear wheel left some remaining electrostatic potential.

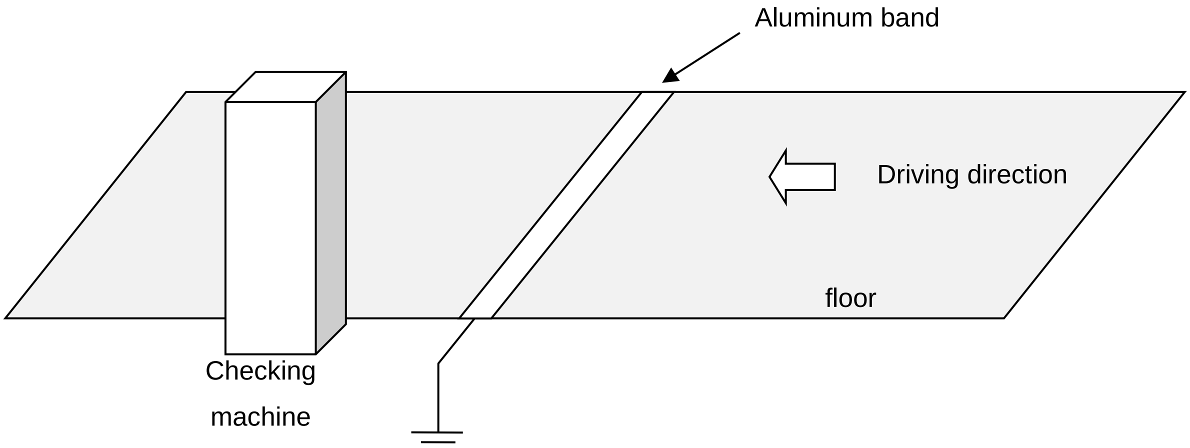

Figure 8. Measuring setup for electrostatic discharge of cars in a parking

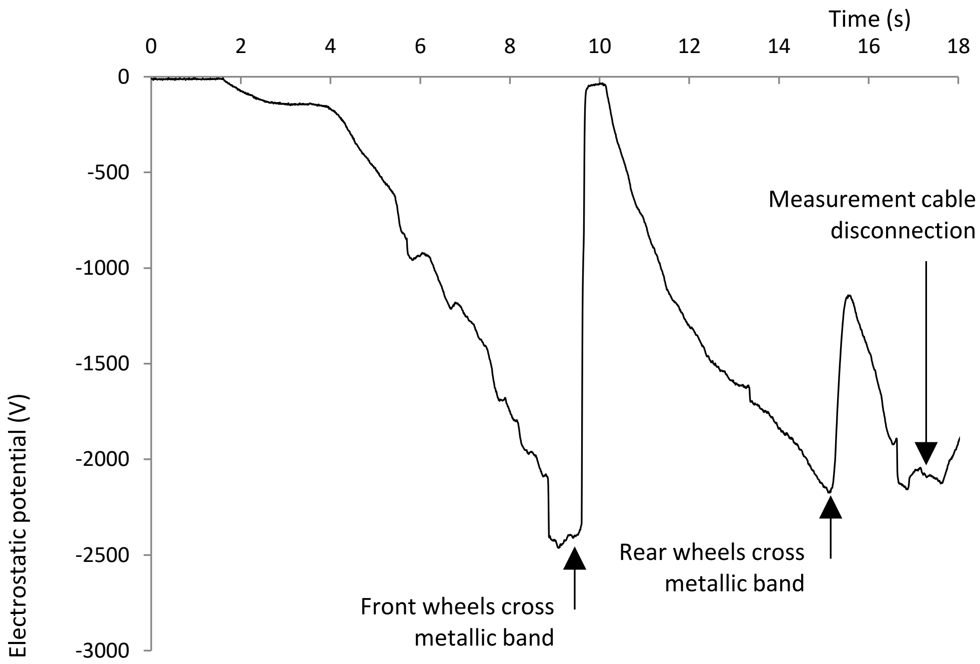

Figure 9. Evolution of the electrostatic potential of a car when crossing the metallic bands.

3.4. Discussion: humidity control.

Some cases were furniture is the origin of charge generation may be easier to solve than electrostatic problems coming from the floor. Humidity control can be more easily achieved in some situations than replacement or modification of floors and furniture. In table 1 [19], the effect of humidity in some processes is shown.

As pointed by [6], humidity control should be based on the dew point temperature which is the key variable for electrostatic control. The ideal dew point temperature is 12ºC and dew point temperatures above 4ºC should be acceptable. The use of dew point can help in optimizing humidity control, however, for homes and offices and for a temperature of 20ºC, as pointed by [6], a simple general rule can be established in keeping the relative humidity between 50% and 60% to reduce electrostatic charge generation. This 50-60% rule is a simple indication for users and can be achieved with humidifiers.

Table 1. Effect of relative humidity of some process (from [19])

Process	Electrostatic potential (kV)	
	Relative humidity 10-20%	Relative humidity 65-90%
Walking across a carpet	35	1.5
Standing from a varnished chair	18	1.5
Walking across a PVC floor	12	0.25

5. Conclusions

Electrostatic comfort concept is proposed to differentiate daily life situations from the safety work conditions context where health, hazards, losses or the presence of explosive atmospheres are critical. The electrostatic comfort has not been generally pointed as a technical problem although a design that takes into account electrostatic comfort needs a good understanding of electrostatics and requires specific solutions. Pedagogy is also very necessary for users. Misunderstandings about static electricity problems are very common, sometimes pointing the electrical installation or AC magnetic or electric fields as the cause of electrostatic discharges.

Electrostatic discomfort can be a source of continuous stress and psychological fatigue. A technical recommendation document (TR) considering electrostatic comfort concept could be very helpful to serve as a reference to designers. It can also be recommended in building codes in order to avoid situations difficult to revert.

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