Charging of a person exiting a car seat

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\textbf{Abstract.} Electrostatic charge is generated by the contact, rubbing together and separation of clothing and car seat upholstery. It is also known that the charging levels will increase in a cold and dry climate. Charge on clothing will induce a separation of charge in the body of the wearer. The net result is an increase in the electrical potential of the body (or body voltage), thereby creating the risk of an electrostatic discharge (ESD) in the form of a spark from the charged human body to a large or earthed conductor. As charge is also bound to the surface of the clothing, brush discharges from the clothing can follow. The effects of sparks from the human body in the environment of a car may be a) to cause uncomfortable and distracting shocks to the person; b) to cause damage or disruption to electronic systems (GPS devices, vehicle management systems, etc); or c) to ignite flammable fuel vapour. A brush discharge from clothing may also ignite fuel vapour and be a risk for (unprotected) sensitive electronic devices (ESDS). The characteristic shape of the discharge current in a brush discharge is very similar to a Human Body Model (HBM) discharge. Measurement systems for determining body voltage and recording brush discharges are described. Results are presented of tests conducted with various combinations of car seat upholstery and clothing in different test environments. The antistatic property of some automotive textiles including conductive threads is emphasized.

\section{1. Introduction}
Most car users are familiar with the occasional electrical shock while exiting the car. This mainly happens during the colder part of the year. The reason for this seasonal dependence, is that the triboelectric charging of fabrics and materials is more pronounced at low humidity e.g. during the winter period. This may not be true in the general case; however for most materials/fabrics it is acceptable as a guideline.

When a driver or passenger slides across a car seat, the seat covering and the person’s clothing become charged \cite{1}. As the person rises from the seat, the charge remaining on the clothing induces charge separation in person’s body. One half of the separated charge couples with charge of opposite polarity on the clothing, whilst the other half of the separated charge couples to the nearest ground.
The capacitive coupling of this latter charge to earth causes the potential of the person’s body to increase.

If the body potential is 10 kV and the capacitance between the person and ground is 150 pF, then the total amount of charge is 1.5 µC and the total electrostatic energy is 7.5 mJ. This amount of energy released as a spark discharge can ignite certain air/gas mixtures, damage some protected electrical devices and many unprotected sensitive electrical devices. One should not forget that an equal amount of charge is bound to the surface of the charged fabric. The capacitance between a person’s body and a jacket can be approximated to 1 nF (in case of loose fit and standing operation), and if only a part of the jacket is charged, as in our case less than half, this implies a capacitance of about 0.5 nF. If one assumes that the jacket is charged homogeneously then one can estimate the average potential difference to 3 kV between the body and the jacket. The energy contained, calculated with this simple model, is then about 2 mJ. This amount of energy and charge can not be released at one time, since the discharge mechanism from an insulator is by brush discharges which are local phenomena, in comparison to spark discharges which are non-local phenomena. Since only a fraction of the total charge amount can be released at once, these brush discharges are not so incendive as a spark discharge from the person’s body. There is also another reason why a brush discharge is less incendive than a spark discharge [2]. They have different topological characteristics; a spark discharge has one or few main channels of charge propagation and a brush discharge is built up by a brush (tree) structure, which congregates to one main channel close to the conductor. The topological difference between the two types of discharges implies that the energy is dissipated over a larger region of space in case of a brush discharge than in case of a spark, resulting in higher local temperatures for a spark discharge.

When it comes to the question of possible damage to sensitive electronic devices, there is also an important difference between the two cases, depending on the amounts of charge involved. However, since the characteristic shape of the discharge current for a brush discharge is very similar to a Human Body Model (HBM) discharge [3-5, 7] the topological difference between the two kinds of discharges does not automatically imply that the brush discharge is less threatening to sensitive electronics. Remember the big difference in sensitivity for Machine Model (MM) and HBM discharges; even if both models are spark discharges there are big differences in the characteristic shapes of their discharge current.

The purpose of the present studies is a) to establish the level of charging that can be expected when a person rises from a car seat, b) to record and analyze brush discharges from charged clothing, and c) to determine if textile technology used to control static electricity in other application can be used to reduce tribocharging in car seats. In the process of conducting these studies a number of measurement procedures were used: measuring body potential when rising from car seats, measuring brush discharges from charged clothing and measuring charge generation using table-top apparatus. The relationship between these procedures was also investigated. The relationship between the table-top measurements and those involving actual car seats is an important issue for car manufacturers because measurements involving cars and car seat are time consuming and expensive and test conditions are more difficult to control compared to table-top measurements that can be conducted under controlled laboratory conditions.

2. Experimental setup
The experimental work was carried out at three locations. In each location different environmental conditions were used and controlled to different degrees. In a controlled environment at the Swedish National Testing and Research Institute, SP, in Borås Sweden, a low relative humidity (12%) at a temperature of 23°C was used. This corresponds to an indoor environment during the winter period and to that of a car with climate control. At BTTG’s laboratory in Leeds, UK the environment was controlled at 26% relative humidity and 23°C. The environmental conditions were not precisely
controlled at the third location, Technocentre Renault, Guyancourt, France, but sets of measurements were made on the same day at either 33% or 37% relative humidity.

Body voltage was measured at all three locations using similar methods. At Renault, body voltage was measured on a test subject sitting in and getting out of a car. Voltage was measured and recorded using a capacitance divider probe [1]. Measurements at BTTG were made using a car seat installed on a platform that positions the seat in the same geometry found in a typical car. Body voltage was measured using a JCI 140F/148 electrostatic voltmeter connected to a digital storage oscilloscope for recording purposes [10]. A car seat was also used at SP in a similar way to BTTG – see figure 1 – and body voltage measurements were made using an electrostatic voltmeter [9]. When the charging level was stable, the charged person dropped the voltmeter electrode and discharged herself to a Charge Plate Monitor (CPM). The stabilised peak voltage of the body was registered and the amount of charge as well as the discharged energy was calculated using the obtained information.

A similar test procedure was used in each laboratory. The test subject wears either a reference garment (polyester/cotton coverall) or other clothing chosen by the individual laboratory. The reference garments are nominally identical coveralls supplied by Renault. Footwear is chosen to ensure that the test subject has a high resistance to ground when standing upright. The test subject sits in the car seat, either in a laboratory (SP & BTTG) or in a car (Renault). Whilst holding the input electrode of the voltmeter (SP & BTTG) or capacitance divider probe (Renault) the test subject get out of the seat in a normal way and stands upright. This sequence is repeated several times with the body voltage profile being recorded each time. The car seats used in each laboratory are similar but not identical and are all covered with polyester upholstery typical of most production cars with fabric upholstery. SP also used a car seat with leather upholstery. Additional tests are performed with three upholstery fabrics containing conductive yarns in various configurations. These fabrics are secured around the car seats and although they are not closely fitted to the seat, they do represent an acceptable approximation to a car seat made with the fabrics.
At SP, when the charge on the body had partly discharged to the CPM and the charge amount was noted, the test person grounded herself. An attempt to obtain discharges from the garment was made, and the captured discharges were detected with a shielded probe [5], connected to the oscilloscope. The discharge current as a function of time was recorded and the amount of transferred charge was calculated [9].

A special experimental tool was designed at Renault with the aim to reproduce a movement close to that occurring when a person exits a car [8]. Indeed, Renault’s experience in this field showed that antistatic properties of automotive textiles can be characterized on-table in a reliable manner only if tribocharging is representative of what happens in the vehicle. A continuous charging by friction does not accurately simulate a person getting up from the car seat. Contact and separation between two textiles, with a sliding movement more closely nears their goal. This reflection led to the test equipment that is described in reference [8]. The person with insulating shoes soles (isolated conductor) is simulated by an isolated stainless steel cylinder covered with the garment textile – see figure 2.

3. Results

The maximum body voltages recorded by the different laboratories in various test configurations are shown in table 1. The values represent the average recorded voltages for a number of trials within each test configuration. Also shown in table 1 is the energy stored on a human body, with the capacitance of 150 pF, at the corresponding body voltage level.

| Laboratory | Seat / Cover | Garment | Body Voltage (kV) | Stored Energy (mJ) |
|------------|--------------|---------|-------------------|--------------------|
| Renault    | Regular Seat in Car / No Additional Cover | Reference Garment (Polyester/Cotton Coverall) | 6.66 to 18.00* | 3.33 to 24.30* |
| SP         | Leather Seat / No Additional Cover | 100% Cotton Coat | 10.02 | 7.53 |
| SP         | Polyester Seat / No Additional Cover | Polyester/Cotton Coat | 12.40 | 11.53 |
| SP         | Polyester Seat / No Additional Cover | Reference Garment (Polyester/Cotton Coverall) | 16.29 | 19.90 |
| BTTG       | Polyester Seat / No Additional Cover | Reference Garment (Polyester/Cotton Coverall) | 9.58 | 6.88 |
| BTTG       | Polyester Seat / No Additional Cover | 100% Cotton Jeans & Jacket | 14.04 | 14.78 |

* Dependent on the type of upholstery.

Measurements were made at SP of the charge transfer and peak current in brush discharges from the surface of the polyester/cotton coat after the test subject had risen from the polyester upholstered seat and discharged as described above. A total of five discharges were recorded and the measured values of charge transfer were between 1 nC and 10 nC with the corresponding peak current ranging from 10 mA to 100 mA.

Table 2 shows the results of body voltage measurements made in all three laboratories and voltage measurements recorded from the cylinder of the experimental equipment shown in figure 2. For each laboratory, control refers to the regular polyester upholstered seat. The additional seat covers are described as grey, check and black. The grey and check fabrics contain a core-conductive fibre and the black fabric contains a surface-conductive fibre. Typical voltage profiles are shown in figure 3. The values shown in table 2 correspond to the plateau voltage, i.e. the steady voltage after any initial peaks. The origin of the peaks is explained in the referenced literature [1, 10].
Table 2. Voltages recorded with additional seat covers.

| Sample        | Plateau Voltage (kV) |
|---------------|----------------------|
|               | Renault (Ve) | Renault (Cy) | BTTG (Re) | BTTG (Own) | SP (Re) | SP (Own) |
| Control       | 6.66        | 0.79        | 9.58      | 14.04      | 16.29   | -9.00    |
| Grey          | 1.33        | 0.21        | 2.61      | 4.33       | 5.13    | -2.66    |
| Check         | 0.76        | 0.03        | 2.59      | 3.57       | 5.66    | 4.30     |
| Black         | 0.63        | -0.13       | <0.3*     | 0.64       | 0.85    | -1.40**  |
| Rel. Hum.     | 37%         | 33%         | 26%       | 26%        | 12%     | 12%      |

*In this case body voltage was sometimes negative and sometimes positive, but always a low value.
** High variability between repeat measurements, average value shown.

Key to table 2:
- Renault (Ve) – measurements made at Renault from a seat in a vehicle.
- Renault (Cy) – measurements made using Renaults experimental equipment.
- BTTG (Re) – measurements made at BTTG with reference garment.
- BTTG (Own) – measurements made at BTTG with cotton jeans and jacket.
- SP (Re) – Measurements made at SP with reference garment.
- SP (Own) – Measurements made at SP with 100% cotton coat.

4. Discussion and conclusions

Table 1 shows that a high level of charging occurs when people get out of regular car seats in moderate to low humidity conditions and that consequently their body voltages can increase dramatically. The corresponding stored energy on the body is more than five times the minimum ignition energy (MIE) of common hydrocarbon fuels, which are in the range of ~ 0.2 mJ to 0.6 mJ. Not all the energy stored on the body would be released in a spark discharge but nevertheless these values are so much greater than the fuel’s MIE that one expects sparks discharges from such highly charged bodies to be incendiary (Tolson [12] and Wilson [13] concluded that an energy of about four to five times the MIE of a fuel is required to give rise to incendiary discharges from the human body).

The charge transfer measured in brush discharges from clothing was in the range of 1 nC to 10 nC, which is below the level that is expected to cause ignition of hydrocarbon fuels (Wilson [11] suggested that a charge transfer of ~ 100 nC was required to ignite a fuel with 0.25 mJ MIE). The brush discharges reported here correspond to a HBM discharge of between 15 V and 150 V. This is well below the threshold voltage for most protected systems, but there are many individual electronic components within automotive electrical systems that have voltage thresholds below 100 V HBM. If such devices are exposed to brush discharges from clothing, for example when servicing a vehicle, damage or disruption would be expected.
One way to mitigate the risks associated with high levels of charge on the human body is to reduce the generation of charge at source. The results shown in table 2 indicate that tribocharging can be reduced by incorporating small quantities of conductive yarn into upholstery fabric. In the case of the three fabrics included in this study, the voltage generated is always lower compared to regular upholstery. However, it is only the Black sample (with surface-conductive fibres) that maintains voltages below 4 kV across the board. 4 kV is an accepted upper limit for body voltage. Below this level, painful shocks are not generally felt and the risk of igniting fuel vapours is minimal [11, 12].

The results in table 2 illustrate a number of aspects of tests involving tribocharging. Firstly is the effect of relatively humidity. As the relative humidity decreases from over 30% at Renault to 12% at SP, there is a corresponding increase in recorded voltages. The relative change is not the same for all materials indicating that each material responds to changes in humidity to a different degree. Such variation makes it difficult to make absolute comparisons. Add to the variation caused by changes in humidity, are those caused by other factors, including the geometry of the car seat, the size and weight of the test subject, the age and cleanliness of test materials and differences in measuring instruments. When one considers all these factors it is not surprising that there is little agreement between the absolute values shown in table 2. Nevertheless, the agreement in the ranking order of the three fabric and the control seats is very good from laboratory to laboratory. The table-top test developed by Renault shows some promise as a means of predicting general trends. It may therefore be useful as a screening test to select materials before making actual car seats.

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