



# Electrostatic charging of vehicles being driven and stopped

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## ABSTRACT

In this work, the electrostatic charging of vehicles was intensely investigated in the dry climate of Spain. The vehicles used in this study include forklifts, passenger cars, vans, trucks and tractor-trailers, loaded and unloaded. The measuring results obtained while these vehicles were being driven and stopped are presented in this work together with the variables identified. An equation on the potential of two rubbed objects given by Schön was applied on the charging process of tire and street yielding a calculation that simulated the measured potentials on the vehicles body within the experimental scatter. Based on this calculation, safety conclusions and recommendations for threshold limits were derived.

## 1. Introduction

While they are being driven or stopped, vehicles may become electrostatically charged under certain conditions [1–10]; this fact has been known since the 1940s [8]. This electrostatic charge may have the following effects: see Figs. 1 and 2

- damage to electronic devices touched by the driver (e.g. parking meters) [1–3].
- ignition of gasoline vapors if the accumulated charge present in the vehicle discharges in the presence of gasoline vapors [1–7,9,10].
- electric shocks that may be dangerous for passengers with pacemakers [1,2,6].
- damage to electronic devices in the vehicle due to local overvoltages or interfering HF waves created by local discharges [1,6].
- poor radio reception due to interfering waves created by electrostatic discharges [1,8].

For this reason, the electrostatic charging of vehicles was systematically investigated under worst-case conditions at CEMA, the Michelin tire test center in Cabo de Gata, a half-desert near Almería, Spain. The experimental set-up, the results obtained, the variables identified for charging, a calculation of the results and a safety discussion are given in the following sections.

## 2. Experimental set-up

### 2.1. General

A Testo 608H2 hygrometer (measuring uncertainty 2% for relative humidity and 1 K for temperature) was used to check the climate conditions before and after each experiment. The temperature was always between 19 °C and 21 °C. The relative humidity is given in the respective text. Before the experiments were carried out, all instruments including the hygrometer were checked to ensure that the values they displayed were within the uncertainties stated by their manufacturers.

### 2.2. Electric potential of the vehicle ( $U$ )

The best method for measuring the electric potential ( $U$ ) of the vehicle while being driven was to determine the electric potential difference between the charged vehicle and the uncharged vicinity in field meter units (FU); here, a field meter (EMF 58 from Eltex, Germany, measuring uncertainty 10% at full scale) was held out of the vehicle toward the vicinity (Fig. 1). For this reason, the earth point of the field meter was connected to the vehicle body via a shielded cable. The shield was connected to +12 V of the local power system. The shield was necessary because, without it, the charged clothes of the person performing the measurement may have interfered with the potential of the car when the cable moved close to it.

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Fig. 1. Measuring the difference between the vicinity and the vehicle body with a field meter.

This method yielded stable signals that increased linearly with speed and immediately dropped to zero when changing from insulating to dissipative tracks. This method was chosen because it allows voltages to be measured during driving without any contact to the outside. Only one limitation was found: Cars with plastic parts near the field meter (e.g. plastic fenders) may produce a noise signal (in our case 1 FU) if the fenders become charged by dusty air during driving. However, this offset signal can be easily detected by driving the vehicle over conductive roads.

The maximum signal was obtained when holding the meter horizontally as far as possible away from the vehicle. There was only one needle-width decline when the angle was changed to  $\pm 45^\circ$  from horizontal. Further increasing the angle, however, made the signal decrease to zero, as the field meter then began to measure the voltage of the car body in reference to itself.

The potential on the vehicle corresponding to 1 FU was determined by directly measuring the voltage on the vehicle body by means of an electrostatic voltmeter that was connected to the ground via a long wire; this measurement took place while the vehicle was being driven in a circle. It was found that 1 FU corresponds to between 800 V and 900 V. In this document, 1 FU was correlated with 1000 V to avoid any underestimation of the built-up voltages.

### 2.3. Electrical leakage resistance to ground of the vehicle ( $R_v$ )

The electrical leakage resistance to ground ( $R_v$ ) of a vehicle is one of the determining parameters for the charge generation on the vehicle during moving. It depends on the electrical resistance of each tire from the rim to the ground  $R_t$ , measured according to WdK110 [11,12] or ASTM 1971 [13] according to the following formula:

$$1/R_v = 1/R_{t1} + 1/R_{t2} + \dots + 1/R_{tn} \text{ with } n = \text{number of tires of the vehicle.}$$

If all tires have the same resistance (this is only approximately the case in practice),  $R_v$  is inversely proportional to the number of tires of the vehicle.

$R_v$  was measured according to IEC 60079-32-2 [14] while the vehicle was standing on a conductive floor. A Teraohmmeter (LEM UNILAP ISOX, measuring uncertainty less than 2%) was connected

between the vehicle body and a contact point on the floor near the vehicle. The concrete floor in a repair hall, which was highly conductive (the lowest value measured between vehicle body and contact point to the floor via the tires was  $2 \text{ k}\Omega$ ), was used for this purpose. As high resistances decrease strongly with increasing voltage, the measuring voltage and measuring time stated in IEC 60079-32-2 [14] were applied (start with 10 V ( $R_v < 1 \text{ M}\Omega$ ), then 100 V ( $R_v < 10 \text{ M}\Omega$ ), 500 V ( $R_v < 100 \text{ M}\Omega$ ) or 1000 V ( $R_v > 100 \text{ M}\Omega$ )).

### 2.4. Leakage resistance to ground of the road ( $R_l$ )

$R_l$  was measured according to IEC 60079-32-2 [14] by means of a  $20 \text{ cm}^2$  metal electrode on the surface of the track; this electrode was coated with conductive foam compressed with about 10 kg of pressure. The Teraohmmeter described in 2.3 was connected between this metal electrode and a metal rod pushed into the earth near the measuring point. As high resistances decrease strongly with increasing voltage, the measuring voltage and measuring time stated in IEC 60079-32-2 [14] were applied (see 2.3 for details). The results obtained are quite like those obtained when using other standard testing methods for flooring resistance (e.g. Refs. [14–17]).

### 2.5. Electrical equivalent capacitance of the vehicles ( $C$ )

The equivalent electrical capacitance of the vehicle ( $C$ ) was measured according to IEC 60079-32-2 [14]. The vehicle was stationed on insulating plastic mats (about 0.2 mm thick) that had been laid on the concrete floor of a repair hall (Fig. 2). The concrete floor was a conductive surface that clearly exceeded the vehicle's dimensions, as required in the standard cited. A battery-operated capacitance measuring bridge (Escort ELC-131-D, measuring uncertainty less than 2 pF, measuring function *series mode* (capacitance and resistance in series)) was connected between the vehicle body and a contact point on the floor near the vehicle, and then disconnected from the vehicle body to achieve the stray capacitance. The capacitance difference between the measurement and the stray capacitance was taken as the electrical equivalent capacitance of the vehicle. This capacitance is a network of capacitors and resistors (e.g. tires), for which reason it is accurately referred to as an “electrical equivalent capacitance”.

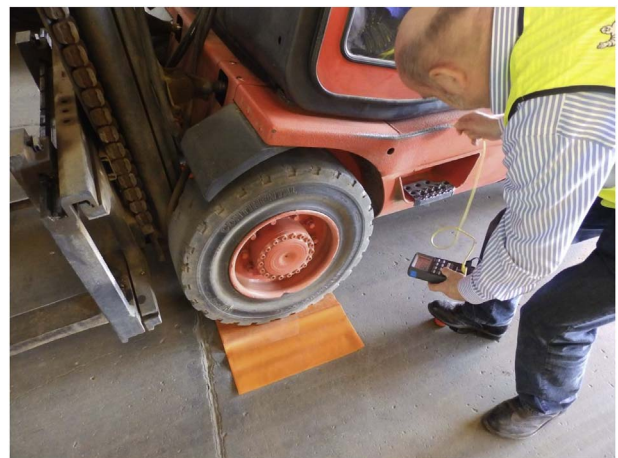


Fig. 2. Measuring the capacitance of the forklift.

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