# Investigating the Performance of Conductive Thick Epoxy Floors

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***Abstract*** - Many companies in Europe are using the floor/footwear system as a primary means for grounding personnel. The ECF are qualified according to the IEC 61340-4-1 based on their Rtg only. The conductive shoes are also qualified based on their Rtg only. We have found in many locations, qualified conductive epoxy floors, used in conjunction with qualified ESD shoes, giving peak voltage values up to 600 volts and very long decay times. This paper reviews the situation in detail.

## Introduction

More and more companies in Europe are using the floor/footwear system as a primary means for grounding personnel. Based on the new international standard, IEC 61340-4-1, the floor resistance to ground, Rtg, should be less than $1.10^6$ ohm for an ECF. The shoe resistance through the wearer should be less than 35 Mohm.

As described in the paper presented at the 1997 EOS/ESD symposium by Mr. Gaertner from Siemens AG (Grounding personnel via the floor/footwear system) " the resistance to ground of the floor (Rtg<$10^9$ ohm) and the footwear (Rtg < $10^8$ ohm) are sufficient to ground an operator during normal operation when working in a standard position." The IEC 61340-4-1 does not specify a walking test and most companies will qualify a conductive floor based on the floor Rtg only, as described in the IEC 61340-4-1. Conductive epoxy floors are widely used throughout Europe in the electronics industry and also in the chemical and the explosives industries where the personnel is grounded through the floor/footwear system and must be held at ground potential for safety reasons. While auditing a new electronic production facility with a large conductive epoxy floor, the floor Rtg was measured according to the IEC 61340-4-1 and was found to be between 18 Kohm and 45 Kohm. The floor was then qualified as an ECF. While performing the walking test, which was not needed for the qualification, peak values of more than 600 volts were measured. The conductive shoes had a Rtg of 2,5 Mohm. The same tests, performed at other locations that used a different conductive epoxy floor from another manufacturer, presented also the same problem. It should be noted that two reputable European companies manufactured these epoxy floors. At this stage, we decided to investigate the performance of the epoxy conductive floor/footwear system under laboratory conditions. We have contacted the two companies who produced the epoxy materials for the floors we have tested in the field, and we have received from them two plates made from the standard formulation they are using. The low Rtg and resistance point to point of both floors on one hand and the relatively high voltages on the person performing the walking test on the other hand, suggested that the standard conductive PU shoe soles available on the market created a high charge during the separation process between the soles and the epoxy floors. We decided to make laboratory samples of a more conductive PU material and check its performance. The walking test evaluates the performance of the footwear/floor combination. The decay time was measured when the person stopped walking. According to the data presented by Mr. Gaertner in his EOS/ESD 1997 paper, the shortest time needed by a person to touch a component is 0,3 second. This decay time was measured from the voltage value reached when the person stopped, to 100 Volt, which is the highest acceptable voltage in an EPA. For comparison purposes, conductive and dissipative rubber floor materials, conductive and dissipative PVC floor materials and a dissipative carpet tile floor material have been tested.

## Test set-up

Resistance meter measuring at 10 Vdc and 100 Vdc. Two 2,25 kg probes fitted with a conductive rubber electrode. The probes conform to ANSI/EOS/ESD-S4.1-1990.
One concentric ring probe fitted with conductive silicone rubber electrodes for surface resistance measurement. The probe conforms to ANSI/EOS/ESD-S11.11-1993.
Novx series 5000 ESD monitoring instrument with an analog output linked to a laptop via an A/D converter. The Novx 5000 has a measuring range of 0 to 5000 V and an input impedance > 100 Gohm.

## Floor materials under test

**Material A:** 2mm thickness, 2 component, 3-layer conductive epoxy material. It consists of a sealing layer, covered with a conductive carbon loaded layer. The self-leveling top layer is loaded with conductive fibers. The sample size was 500 x 800 mm and had a groundable point.
**Material B:** Same as material A. The top layer is loaded with different conductive fibers, longer than in material A. The sample size was 500 x 800 mm and had a groundable point.
**Material C:** 2,5 mm thickness, carbon loaded, conductive rubber flooring. The sample size was 600 x 1200 mm, glued with conductive glue to conductive chipboard and had a groundable point.
**Material D:** 2 mm thickness, static dissipative rubber flooring. The sample size was 600 x 1200 mm and was glued like sample C.
**Material E:** 2 mm thickness, carbon loaded, conductive PVC tiles. The sample size was 600 x 1200 mm and was glued like sample C.
**Material F:** 2 mm thickness, carbon loaded, static dissipative PVC tiles. The sample size was 600 x 1200 mm and was glued like sample C.
**Material G:** 3,8 mm thickness, static dissipative carpet tiles, constructed with conductive fibers and static dissipative PVC backing. The sample size was 450 x 900 mm and was glued like sample C.

## Shoes under test

**Shoe # 1:** Conductive clogs with PUR black soles.
**Shoe # 2:** Men's shoes with PUR black soles.
**Shoe # 3:** Conductive clogs with PUR black soles.
**Shoe # 4:** Conductive clogs with PUR white soles.
**Shoe # 5:** Shoe # 3 with an extra 3 mm PUR black conductive material glued with a conductive glue on the original soles. 6 x 6 " laboratory samples of this PUR material were made. The surface resistance of the material is 45 Kohm and the resistance through the material to a metal plate was 7,5 Kohm. The material has a hardness of 75 Shore A.

## Tests performed

All the tests have been performed under laboratory conditions, at a temperature ranging between 19 and 23 deg. C and R.H between 22% and 40%.
**Test # 1:** Shoes resistance through the wearer to a metal plate, measured at 100 Vdc.
**Test # 2:** Shoes resistance through the wearer and the floor under test, measured at 100 Vdc.
**Test # 3:** Floor materials resistance, point to point measured with 2 probes at 100 Vdc.
**Test # 4:** Floor materials resistance to a groundable point, measured with 1 probe at 100 Vdc.
**Test # 5:** Average voltage on the person during the walking test.
**Test # 6:** Decay time from stand still to 100 Volt.

## Test results

All the test results are summarized in Table 1.

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Sole hardness Shore A | 65 | 41 | 46 | 52 | 75 |
| Rg through wearer to metal plate | 2,8 Mohm | 4,5 Mohm | 2,6 Mohm | 3,1 Mohm | 5,6 Mohm |

**Material A:** Conductive thick epoxy  Rtg: 40 to 100 Kohm  Resistance point to point: 0,2 to 0,4 Mohm

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 1,5 Gohm | 9,5 Gohm | 8,4 Gohm | 5,5 Ohm | 12 Mohm |
| Average voltage during walking test | -300V | -400V | -200V | -300V | -30V |
| Decay time from stop to 100 V | 1,1 Sec | 17,1 Sec | 0,5 Sec | 1,2 Sec | <0,3 Sec |

**Material B:** Conductive thick epoxy  Rtg: 80 to 100 Kohm  Resistance point to point: 100 to 200 Kohm

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 1,7 Gohm | 4,5 Gohm | 3,7 Gohm | 6,2 Gohm | 11 Mohm |
| Average voltage during walking test | -150V | -220V | -240V | -260V | -25V |
| Decay time from stop to 100 V | <0,3 Sec | 1,0 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

**Material C:** Conductive rubber  Rtg: 20 to 25 Kohm  Resistance point to point: 20 to 22 Kohm

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 6,8 Mohm | 17,4 Mohm | 4,8 Mohm | 8,4 Mohm | 7 Mohm |
| Average voltage during walking test | <10V | <10V | <10V | <10V | <10V |
| Decay time from stop to 100 V | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

**Material D:** Dissipative rubber  Rtg: 30 to 35 Kohm  Resistance point to point: 70 to 78 Mohm

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 15 Mohm | 16 Mohm | 19 Mohm | 17 Mohm | 18 Mohm |
| Average voltage during walking test | 20V | 25V | 15V | 10V | <10V |
| Decay time from stop to 100 V | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

**Material E:** Conductive PVC tiles  Rtg: 0,8 to 1,4 Mohm  Resistance point to point: 4 to 6 Mohm

| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 7,4 Mohm | 22 Mohm | 5,9 Mohm | 11 Mohm | 10 Mohm |
| Average voltage during walking test | 40V | 50V | 30V | 30V | 15V |
| Decay time from stop to 100 V | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

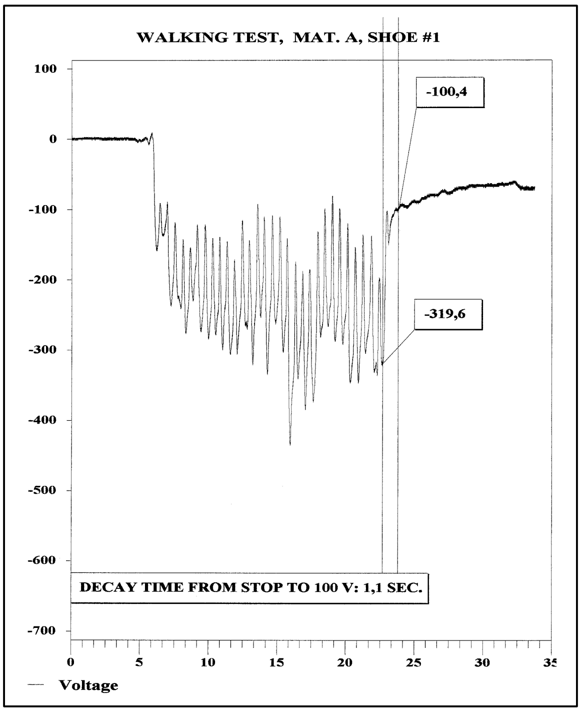
**Material F:** Dissipative PVC tiles  Rtg: 8 to 13 Mohm  Resistance point to point: 31 to 41 Mohm

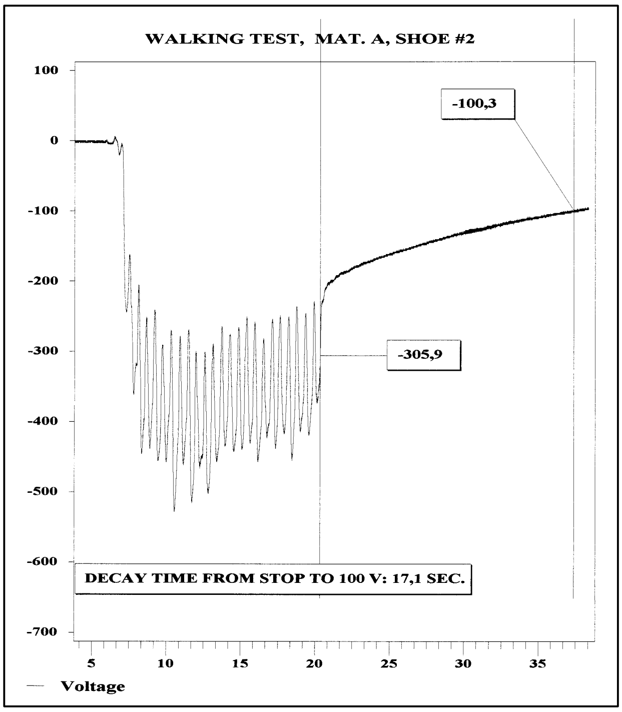
| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 12 Mohm | 28 Mohm | 8,8 Mohm | 14 Mohm | 15 Mohm |
| Average voltage during walking test | 30V | 40V | 25V | 20V | 10V |
| Decay time from stop to 100 V | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

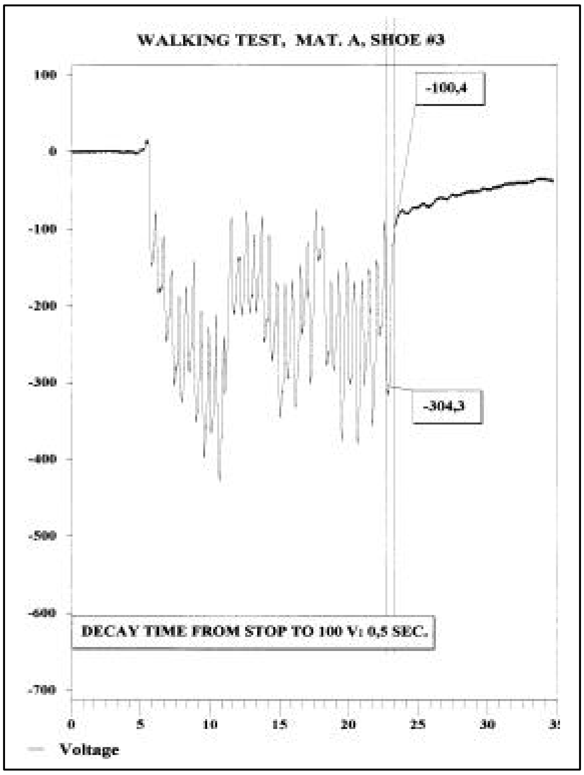
**Material G:** Dissipative carpet tiles  Rtg: 6 to 8 Mohm  Resistance point to point: 18 to 22 Mohm

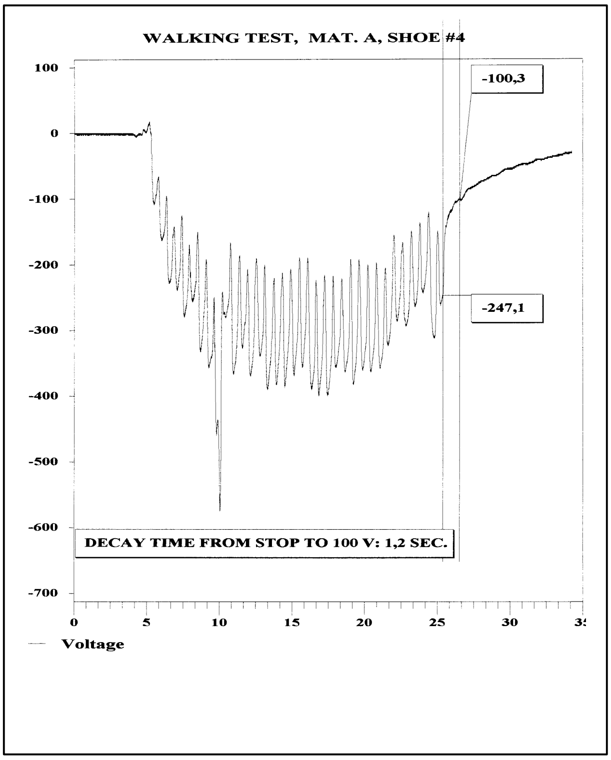
| Shoe | # 1 | # 2 | # 3 | # 4 | # 5 |
|---|---|---|---|---|---|
| Rtg through wearer and floor | 6,2 Mohm | 18 Mohm | 4,1 Mohm | 10 Mohm | 5,8 Mohm |
| Average voltage during walking test | <10V | <10V | <10V | <10V | <10V |
| Decay time from stop to 100 V | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec | <0,3 Sec |

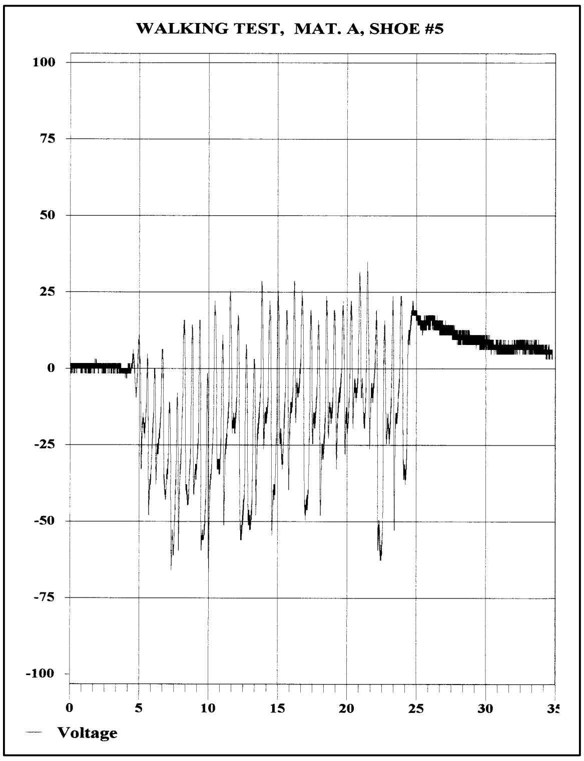
**Table 1**

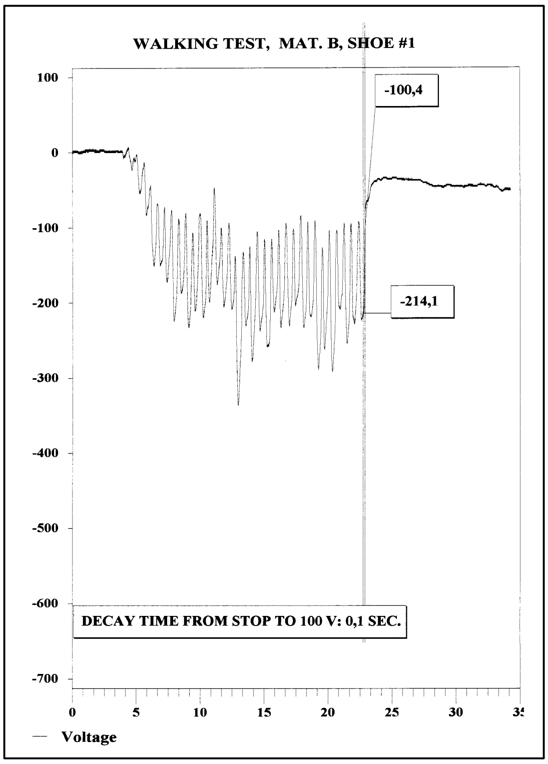

WALKING TEST, MAT. A, SHOE #1
-100,4
-319,6
DECAY TIME FROM STOP TO 100 V: 1,1 SEC.
Voltage

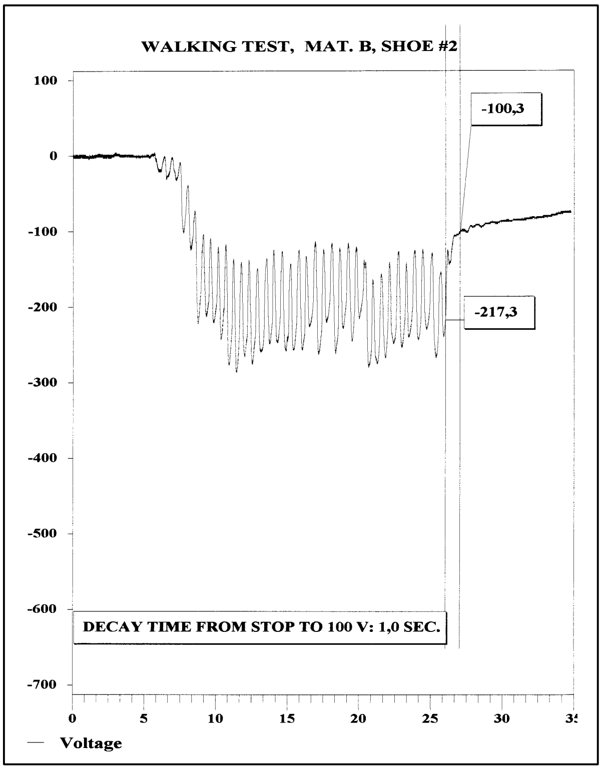

WALKING TEST, MAT. A, SHOE #2
-100,3
-305,9
DECAY TIME FROM STOP TO 100 V: 17,1 SEC.
Voltage

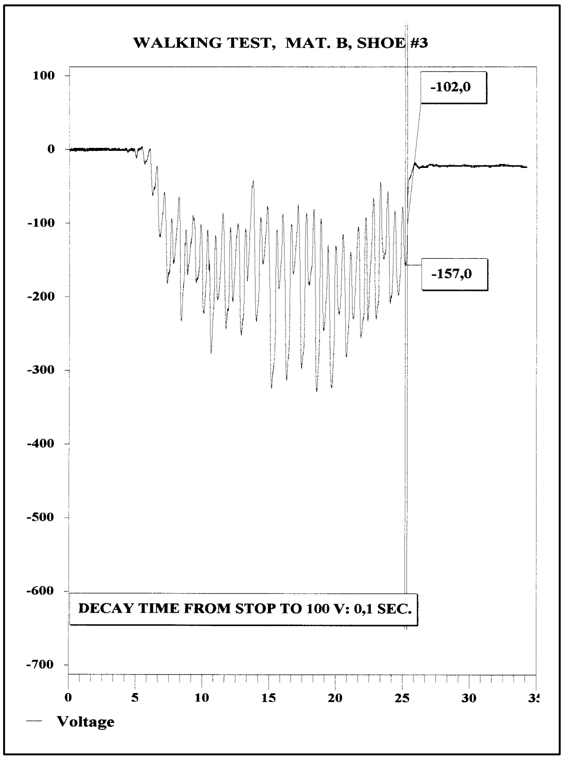

WALKING TEST, MAT. A, SHOE #3
-100,4
-304,3
DECAY TIME FROM STOP TO 100 V: 0,5 SEC.
Voltage

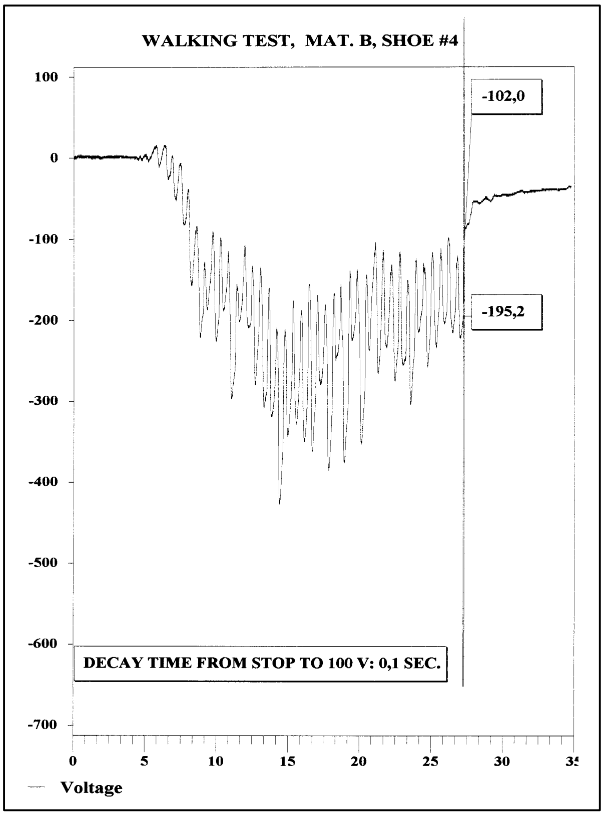

WALKING TEST, MAT. A, SHOE #4
-100,3
-247,1
DECAY TIME FROM STOP TO 100 V: 1,2 SEC.
Voltage

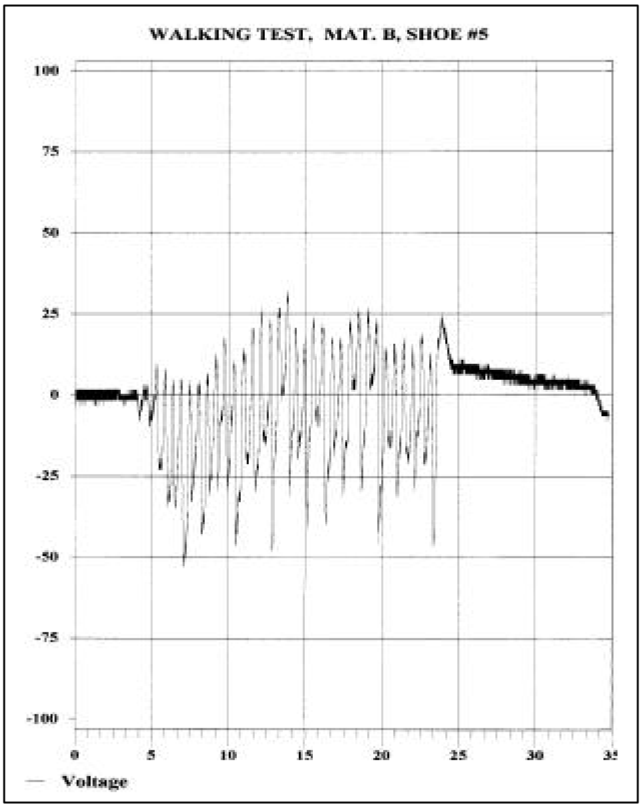

WALKING TEST, MAT. A, SHOE #5
Voltage

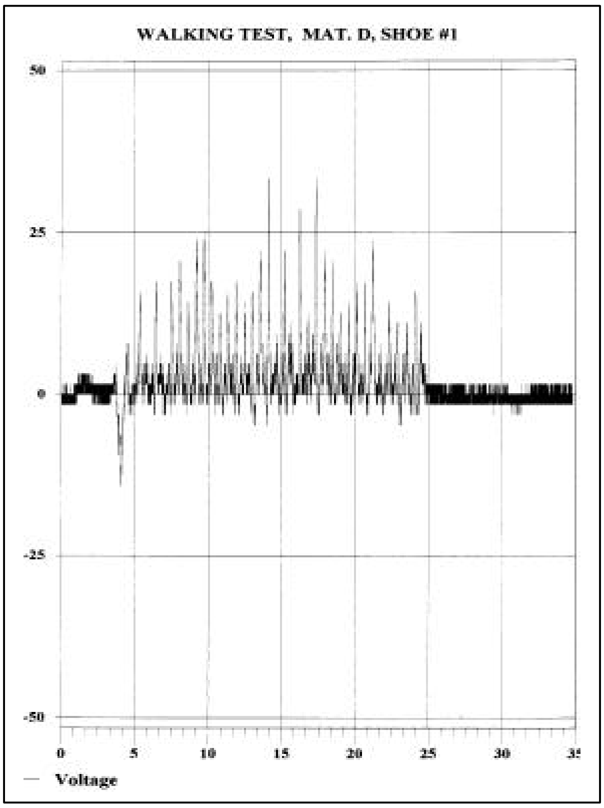

WALKING TEST, MAT. B, SHOE #1
-100,4
-214,1
DECAY TIME FROM STOP TO 100 V: 0,1 SEC.
Voltage

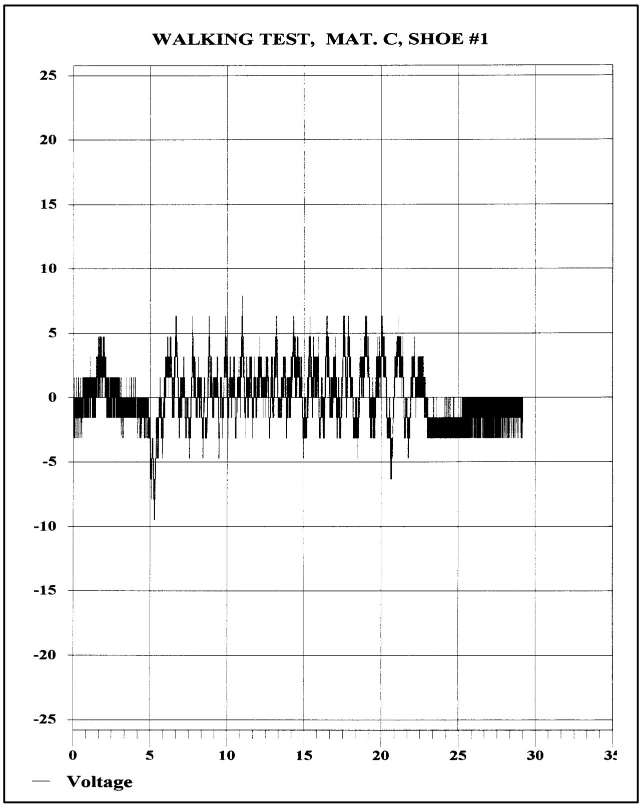

WALKING TEST, MAT. B, SHOE #2
-100,3
-217,3
DECAY TIME FROM STOP TO 100 V: 1,0 SEC.
Voltage

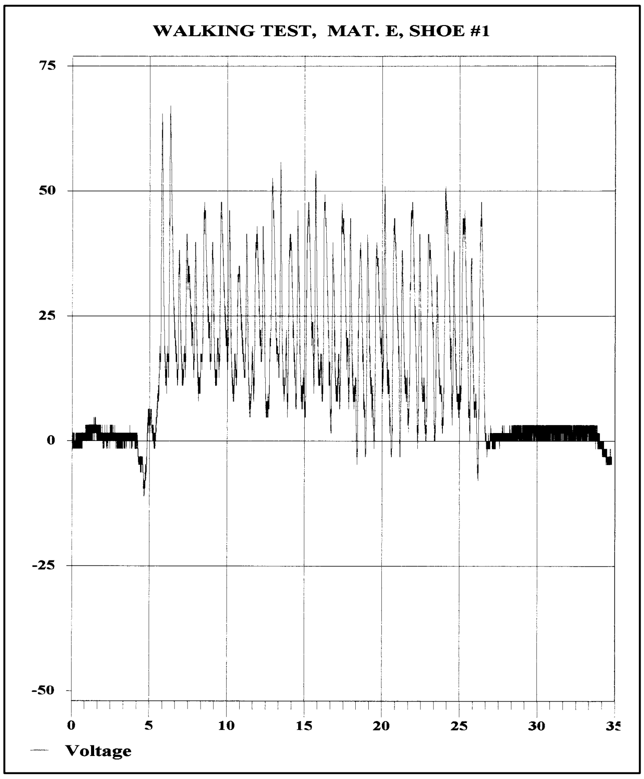

WALKING TEST, MAT. B, SHOE #3
-102,0
-157,0
DECAY TIME FROM STOP TO 100 V: 0,1 SEC.
Voltage

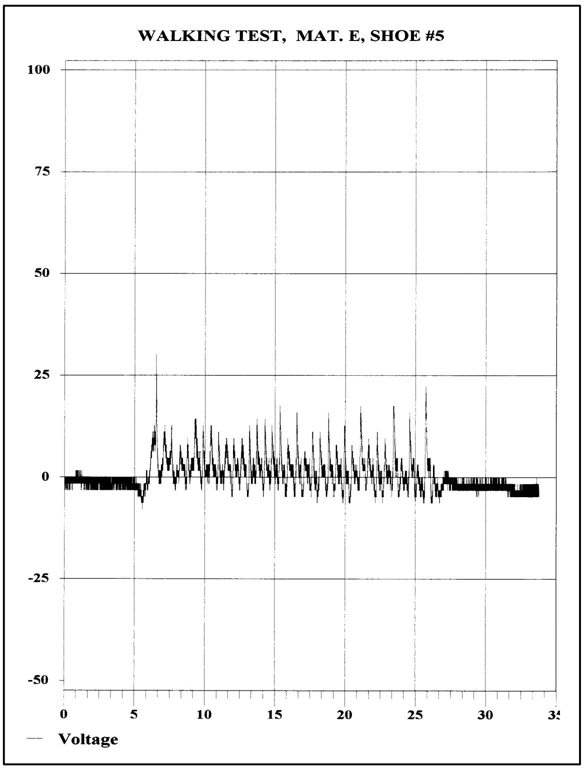

WALKING TEST, MAT. B, SHOE #4
-102,0
-195,2
DECAY TIME FROM STOP TO 100 V: 0,1 SEC.
Voltage

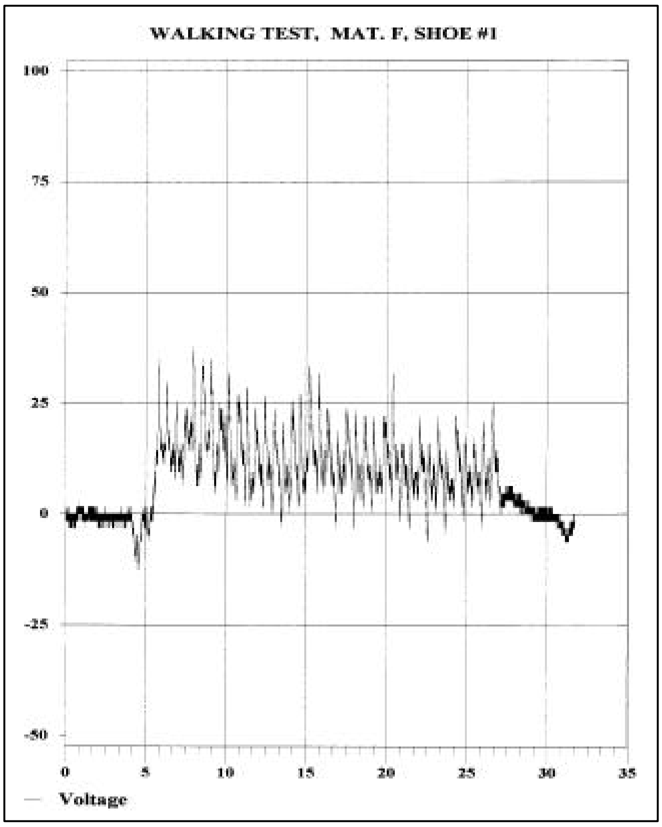

WALKING TEST, MAT. B, SHOE #5
Voltage

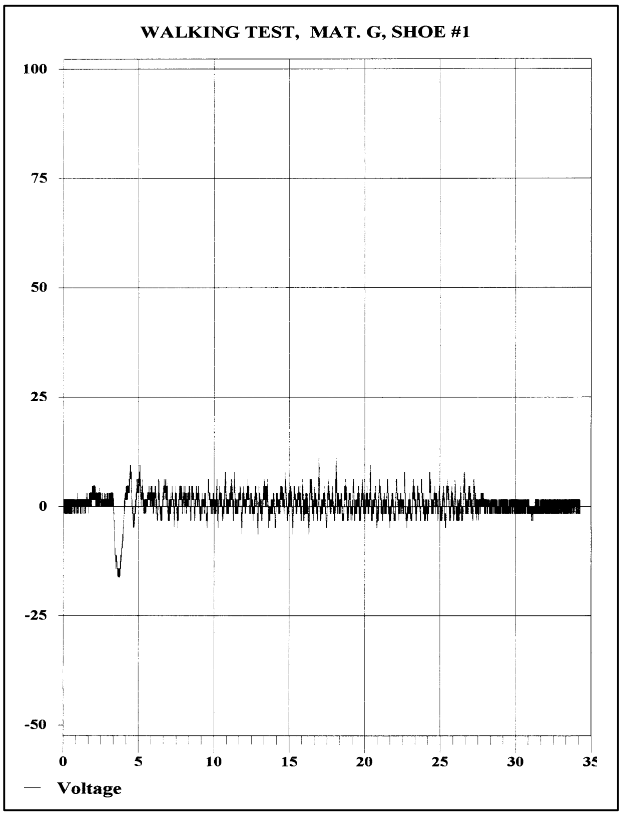

WALKING TEST, MAT. D, SHOE #1
Voltage


WALKING TEST, MAT. C, SHOE #1
Voltage


WALKING TEST, MAT. E, SHOE #1
75
50
25
0
-25
-50
0
5
10
15
20
25
30
Voltage


WALKING TEST, MAT. E, SHOE #5
100
75
50
25
0
-25
-50
0
5
10
15
20
25
30
Voltage


WALKING TEST, MAT. F, SHOE #1
100
75
50
25
0
-25
-50
0
5
10
15
20
25
30
35
Voltage


WALKING TEST, MAT. G, SHOE #1
100
75
50
25
0
-25
-50
0
5
10
15
20
25
30
Voltage

## Test results analysis

### 3 layer conductive thick epoxy floor material A

The material conforms to the IEC 61340-4-1 requirement regarding an electrostatic conductive floor, having a resistance to ground of less than $1.10^6$ ohm. All the shoes tested meet the requirement specified by the IEC 61340-5-1 (T.R-type2) $5.10^4$ ohm <= Rg, = $1.10^8$ ohm. Except shoe #5 (modified shoe #3), the Rtg of the shoe wearer/floor combination, does not meet the IEC 61340-5-1 requirement for a footwear/floor system used as a primary means of grounding personnel. The average voltage on the person during the walking test and the long decay time from stand still to 100 V, disqualify the floor for being used in an EPA. As described by Mr. Gaertner in his 1997 paper, the voltage on the person should drop bellow 100 Volt in less than 0,3 seconds, which is the minimum time required by the person for touching a component. Shoe #5, which is shoe #3, fitted with a 3mm conductive PUR sole, improves the performance of the floor a great deal, and the floor/footwear performance meets the requirement needed for primary means of grounding personnel.

### 3 layer conductive thick epoxy floor material B

The material is similar to material A but the self leveling top layer is loaded with conductive fibers which are longer than those used for material A. Except for shoe #2, the decay time from stand still was less than 0,3 seconds although the average voltages during the walking test were higher than 100 Volt, for shoes #1 through #4. Floor materials C through G exhibited a good performance with all the shoes tested. The average voltage on the person during the walking test was bellow 100 Volt and the decay time from stand still to 100 V (or less) was bellow 0,3 seconds with all the shoes tested.

## Conclusion

Thick epoxy conductive floors are widely used throughout Europe in the Electronics industry. These floors have generally very good mechanical properties. They also look very good and are moderately priced. However it is difficult to predict a homogeneous distribution of the conductive fibers on the self-leveling top layer. It is material dependent but it is also greatly influenced by the person laying down the floor. The manufacturers of the original floors used in the field made the sample plates we have tested. Although they have been made with great care, the materials exhibited the same problems found in the field. The use of longer conductive fibers for a better contact or a higher loading of shorter fibers degrade the esthetical appearance of the floor and are not possible according to the manufacturers. The use of a more conductive PU sole material may help minimize the problem. The minimum 50 Kohm Rtg through the wearer should be taken into account when implementing this solution. The problem could not be discovered without using the walking test, which is an important functional test, when testing the performance of a conductive floor/footwear combination.

## References

**[1]** Reinhold Gaertner; Grounding personnel via the Floor/Footwear System
**[2]** IEC 61340-4-1; Electrostatics- Part 4; Standard test methods for specific applications - Section 1; Electrostatic behavior of floor coverings and installed floors; June 1995.
[**3]** IEC 61340-5-1; Technical report - type 2; Electrostatics- Part 5-1; Protection of electronic devices from electrostatic phenomena- General requirements 1998 - 12.