INDEPENDENT LAB REPORT:
Actual AC & DC Electrical Currents Measured on Conductive and Dissipative Flooring

ANSI 20.20 2007 | ANSI 20.20 2014 | ESD S7.1 | ESD STM97.1 | ESD STM97.2

DISCLAIMER: The contents of this document are not intended to guarantee safety in your work environment. The following information is the result of testing performed on behalf of a Staticworx client and should in no way be interpreted as a comprehensive statement of safety.

Electrical hazards can cause burns, shocks and electrocution (death).

- Assume that all overhead wires are energized at lethal voltages. Never assume that a wire is safe to touch even if it is down or appears to be insulated.
- Never touch a fallen overhead power line. Call the electric utility company to report fallen electrical lines.
- Stay at least 10 feet (3 meters) away from overhead wires during cleanup and other activities. If working at heights or handling long objects, survey the area before starting work for the presence of overhead wires.
- If an overhead wire falls across your vehicle while you are driving, stay inside the vehicle and continue to drive away from the line. If the engine stalls, do not leave your vehicle. Warn people not to touch the vehicle or the wire. Call or ask someone to call the local electric utility company and emergency services.
- Never operate electrical equipment while you are standing in water.
- Never repair electrical cords or equipment unless qualified and authorized.
- Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it.
- If working in damp locations, inspect electric cords and equipment to ensure that they are in good condition and free of defects, and use a ground-fault circuit interrupter (GFCI).
- Always use caution when working near electricity.
- For more information, visit: https://www.osha.gov/Publications/3075.html

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Electrocution Hazard From Conductive Carpet Tiles

Injuries from electrical shocks depend upon many factors including the type and magnitude of current, the resistance of the body at the point of contact, the current pathway, and the duration of the current flow.

Type and magnitude of current

In general, direct current (DC) is less dangerous than alternating current (AC).

The effects of AC on the body depend largely on the frequency; low-frequency currents, 50 to 60 Hz (cycles/sec), are usually more dangerous than high-frequency currents, and three to five times more dangerous than DC of the same voltage and amperage. DC tends to cause a convulsive contraction, often forcing the victim away from further current exposure. AC 60 Hz causes muscular contraction, often "freezing" the hand to the circuit as the fist clenches the current source and may result in prolonged exposure with severe burns if the voltage is high. Generally, the higher the voltage and the amperage, the greater the damage from either type of current. Both AC and DC may affect the body either by altering physiologic functions (involuntary muscular contractions and seizures, ventricular fibrillation, respiratory arrest) or by producing thermal, electrochemical, or other damage (burns, necrosis of muscle and other tissue, hemolysis, coagulation, dehydration, vertebral and other skeletal fractures, muscle and tendon avulsion). Electric shock often causes a combination of these effects.

Threshold of perception

DC entering the hand is about 5 to 10 milliamperes (mA).
AC 60 Hz is about 1 to 10 mA.

"Let-go" current

The maximum current that can cause contraction of the flexor musculature of the arm but still permit the subject to release his hand from the current source.

DC - this value is about 75 mA
AC - this value is about 15 mA

and varies with muscle mass.

A low-voltage (110 to 220v) 60 Hz AC traveling throughout the chest for a fraction of a second may induce ventricular fibrillation at currents as low as 60 to 100 mA; about 300 to 500 mA of DC are required. If the current has a direct pathway to the heart (e.g., via a cardiac catheter or pacemaker electrodes), much lower currents (>1 mA, AC or DC) can produce fibrillation.

Body resistance (measured in ohms/sq. cm)* is concentrated primarily in the skin and varies directly with the skin's condition. Dry, well-keratinized, intact skin has an average resistance of 20,000 to 30,000 ohms/sq. cm, whereas the resistance of moist thin skin is about 500 ohms/sq. cm. If the skin is punctured (from a cut or abrasion or by a needle) or if current is applied to moist mucous membranes, the resistance may be as low as 200 to 300 ohms/sq. cm. A thickly callused palm or sole may have a resistance of 2 to 3 million ohms/sq. cm. As current passes throughout the skin, if the resistance is high, large surface burns can result at both the entry and exit points with charring of tissues in between (heat = amperage squared x resistance). Tissues are also burned internally depending on their resistance; nerves, blood vessels and muscles conduct electricity more readily than denser tissues such as fat, tendon and bone. If the skin resistance is low, the victim may have few, if any, extensive burns but may still suffer cardiac arrest if current reaches the heart.

The pathway of current throughout the body can be crucial in determining injury. Conduction from arm to arm or between an arm and a foot at ground potential is much more dangerous than contact between a leg and ground since the current may traverse the heart. Electrical injuries to the head may cause seizures, intraventricular hemorrhage, respiratory arrest, ventricular fibrillation or asystole, or as a late effect, cataracts. The most common entry point for electricity is the hand, followed by the head. The most common exit point is the foot.

The duration of current flow through the body is important. While the heart is vulnerable to small currents at relatively low voltages, in general the amount of injury to the body is directly proportional to the duration of exposure because tissue breakdown occurs with longer durations allowing internal current flow. Heat is produced by current flow through tissues, causing severe burns, protein coagulation, vascular thrombosis, and tissue necrosis.

When a victim freezes to a circuit, he may suffer severe burns.

**Note: Unlike material resistivity, body resistance is measured in ohms/sq.cm, historically due to the electrode configuration of 1cm x 1cm. This unit has been chosen to show that for differing configurations, the absolute resistance in ohms is dependent on size and spacing of contacts. Please refer to the Merk Medical Manual for further details.

The above discussion is for known voltage sources with known paths through the body. When voltages are applied through unexpected paths, these numbers may be misleading. Even the current levels may be misleading: for example, during a round robin test for the ESD Association, 10 volts was used to determine the resistance of various gloves. No problems were encountered until conductive gloves were tested. Black conductive gloves when worn not only were conductive by the ESD Association’s definitions but the hand hydrated the gloves making the connection to the body very intimate and low resistance. At 10 volts more than 1 mA DC was encountered. This current through the tender (no dead layer of skin) area of the wrist resulted in ruptured capillaries and burns - 1mA DC.

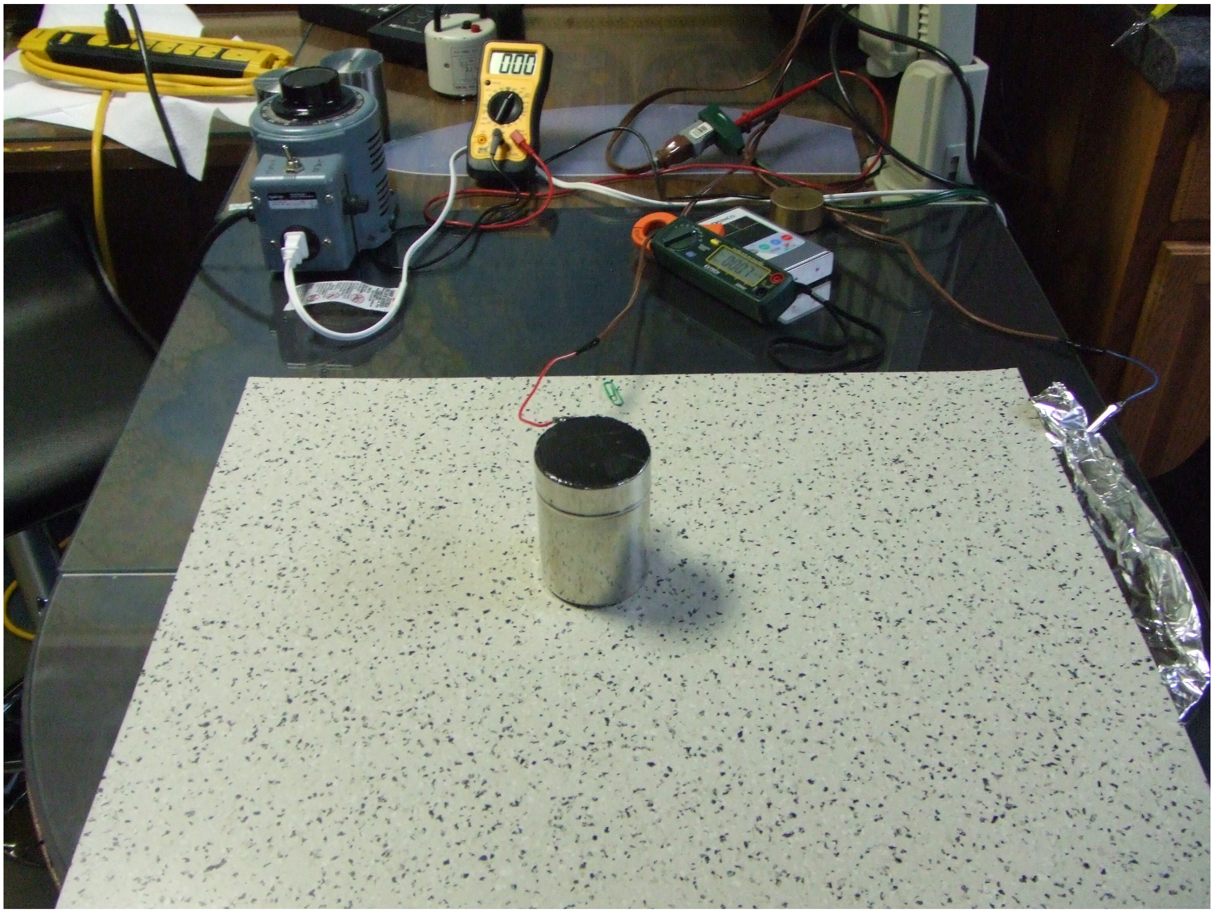
While this is on the level of accepted “threshold of perception” currents, it obviously caused physical damage. If this current was applied across a vital organ, the results would be more tragic.

Also, if an atmospheric condition arises, the current are the result of very high voltages to personnel either tethered to ground or walking with conductive shoes on conductive floors. The levels of danger are not known and the protection circuits should anticipate this.

For this reason, all conductive floor/ tethered personnel areas should be ground fault protected at a minimum.

Alternating Current Test Method

The following set up was used to determine the AC current to ground from the top of the carpet and rubber tiles.



The tile was placed on a large piece of aluminum foil. A 5-pound electrode was placed on top of the tile. The AC voltage was applied from the top electrode to the aluminum foil.

The voltage was controlled by a variac feeding a step up transformer. The voltage applied was measured with a standard multimeter. The AC current was measured with a clamp-on style ammeter.

The voltage was raised slowly and the volts recorded for several “milestone” currents.

The following Tests were conducted on **Conductive Gray Carpet Tiles with Black PVC-free backing**. The tests used alternating current voltages applied from the top of the carpet tile (5 pound metal electrode) through to ground (aluminum foil under tile). **This carpet tile when tested to ESDA STM 7.1 had an average "to ground" measurement of 18,000 Ohms @ 10 Volts DC.**

Conductive Gray Carpet Tiles with Black Backing

AC Volts Volts ac	AC Amperes mili Amps ac	AC Impedance Ohms
4.0	1.0	4000
9.3	2.0	4650
11.5	3.0	3833
15.0	4.0	3750
18.0	5.0	3600
20.2	6.0	3367
30.5	10.0	3050
41.8	15.0	2787
52.3	20.0	2615
74.1	30.0	2470
93.5	40.0	2338
117.0	50.0	2340
139.8	60.0	2330

The threshold of perception is reached with very low voltages. The "let go" current is reached at 42 Volts. Lethal voltages are reached above 120 Volts.

Stephen L Fowler

July 19, 2012

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The following Tests were conducted on **Staticworx ShadowFX Dissipative Carpet Tiles with Vinyl Backing**. The tests used alternating current voltages applied from the top of the carpet tile (5 pound metal electrode) through to ground (aluminum foil under tile). **This carpet tile when tested to ESDA STM 7.1 had an average "to ground" measurement of approximately 3 E 6 Ohms @ 100 Volts DC.**

Static Dissipative Carpet Tiles

AC Volts Volts ac	AC Amperes mili Amps ac	AC Impedance Ohms
5.0	<0.1	N/A
10.0	<0.1	N/A
25.0	<0.1	N/A
50.0	<0.1	N/A
100.0	<0.1	N/A
120.0	<0.1	N/A
150.0	<0.1	N/A
200.0	<0.1	N/A
220.0	<0.1	N/A
240.0	<0.1	N/A

The threshold of perception was never reached.

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The following Tests were conducted on **EC Rubber Tiles**. The tests used alternating current voltages applied from the top of the carpet tile (5-pound metal electrode) through to ground (aluminum foil under tile).

EC Rubber Tiles

AC Volts Volts ac	AC Amperes mili Amps ac	AC Impedance Ohms
31.0	0.1	3.1E5
40.0	0.4	1.0E5
56.0	1.0	1.1E5
66.0	2.0	3.3E4
76.0	3.0	2.5E4
80.0	4.0	2.0E4
93.0	5.0	1.9E4
105.0	6.0	1.8E4
120.0	7.6	1.6E4
At this point the current began to vary greatly due to heating		
124.0	15.7	6.6E3
138.0	18.0	7.7E3
160.0	20.0	8.0E3
240.0	25.0	9.6E3
If the voltage was left in place the current would slowly rise above these levels		

The threshold of perception is reached at about 50 V AC. The “let go” current is reached above 120 V AC. Lethal currents were never reached.

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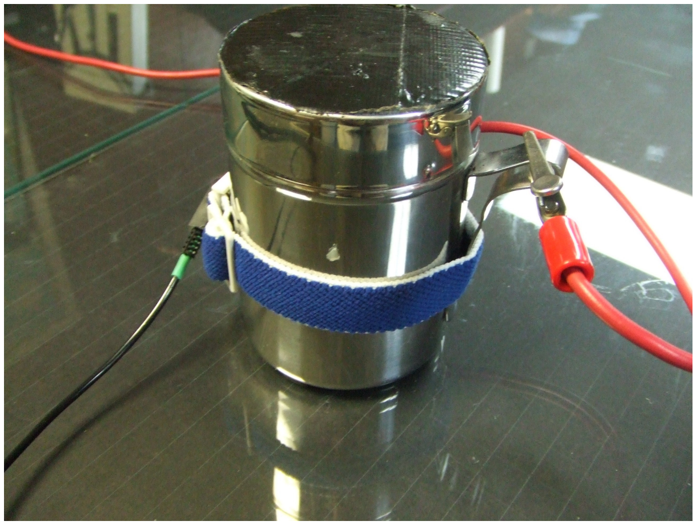
The following Tests were conducted on **a 1 Meg Ohm Wrist Strap**. The tests used alternating current voltages applied through the wrist strap to a metal electrode.



1 Meg Ohm Wrist Strap

AC Volts Volts ac	AC Amperes mili Amps ac	AC Impedance Ohms
120.0	0.1	1.2E6
240.0	0.2	1.2E6

The threshold of perception is never reached.
The "let go" current is never reached.
Lethal currents were never reached.

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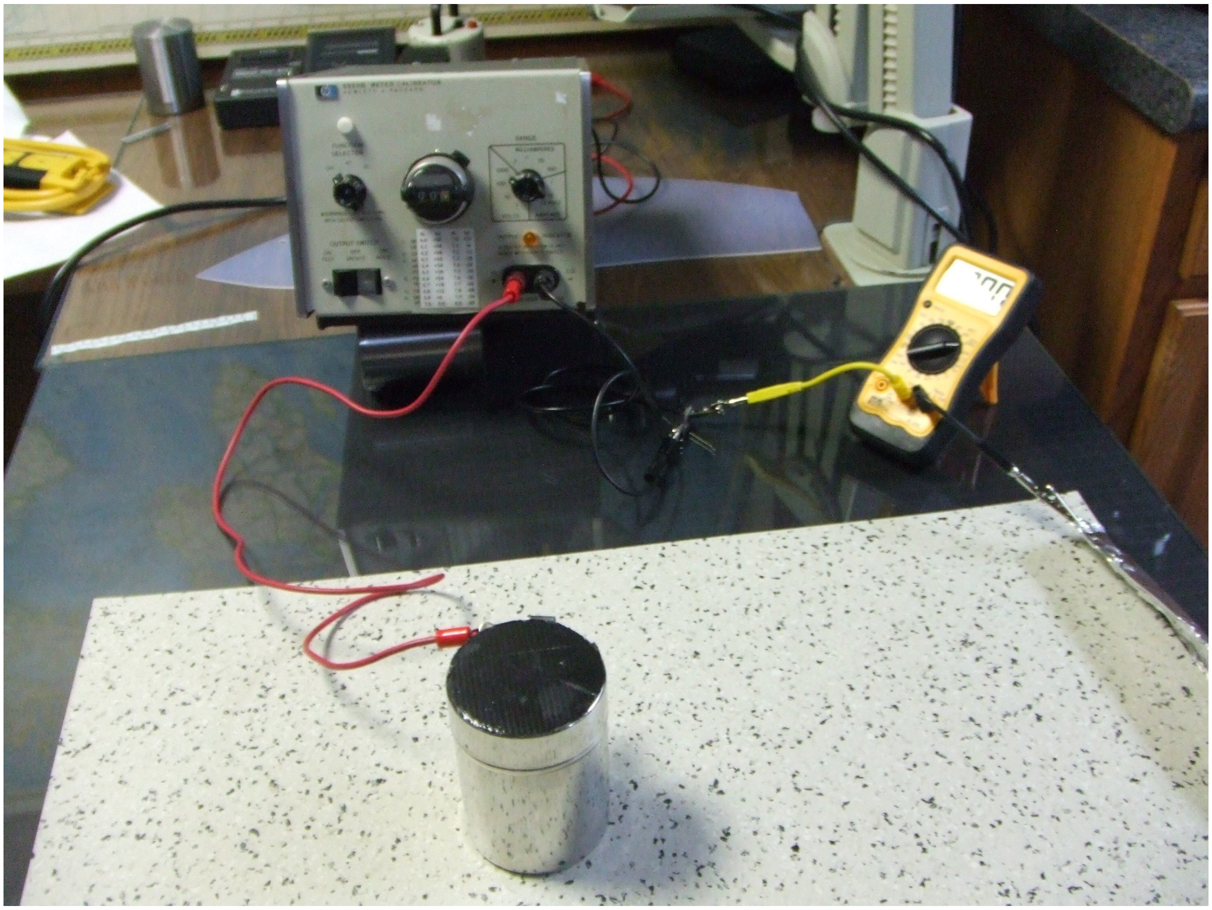
Direct Current Test Method

The following set up was used to determine the DC current to ground from the top of the carpet and rubber tiles.



The tile was placed on a large piece of aluminum foil. A 5-pound electrode was placed on top of the tile. The DC voltage was applied from the top electrode to the aluminum foil.

The voltage was controlled by an HP Meter Calibrator voltage source. The voltage applied was determined by the calibrated dial readings. The DC current was measured with a standard multimeter.

The voltage was raised slowly and the volts recorded for several “milestone” currents.

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The following Tests were conducted on **Conductive PVC-free Gray Carpet Tiles**. The tests used direct current voltages applied from the top of the carpet tile (5-pound metal electrode) through to ground (aluminum foil under tile). **This carpet tile when tested to ESDA STM 7.1 had an average "to ground" measurement of 18,000 Ohms @ 10 Volts DC.**

Gray Carpet Tiles with Black Backing

DC Volts Volts dc	DC Amperes mili Amps dc	DC Impedance Ohms
21.0	5.0	4200
34.0	10.0	3400
48.0	15.0	3200
59.0	20.0	2950
75.0	31.0	2400
100.0	39.0	2564
120.0	52.1	2300
172.0	75.0	2309
240.0	104.8	2290

The threshold of perception is reached at 21 volts.
The "let go" current is reached at 172 volts.
Lethal voltages are never reached.

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The following Tests were conducted on **Staticworx ShadowFX Dissipative Carpet Tiles**. The tests used direct current voltages applied from the top of the carpet tile (5 pound metal electrode) through to ground (aluminum foil under tile). **This carpet tile when tested to ESDA STM 7.1 had an average "to ground" measurement of approximately 3 E 6 Ohms @ 100 Volts DC.**

Staticworx, ShadowFX Dissipative Carpet Tiles

DC Volts Volts dc	DC Amperes mili Amps dc	DC Impedance Ohms
> 300	< 0.1	N/A

The threshold of perception was never reached.

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The following Tests were conducted on **Staticworx EC Rubber Tiles**. The tests used direct current voltages applied from the top of the carpet tile (5-pound metal electrode) through to ground (aluminum foil under tile).

Staticworx, EC Rubber Tiles

DC Volts Volts dc	DC Amperes mili Amps dc	DC Impedance Ohms
91.0	0.5	1.4E5
138.0	1.0	7.7E5
212.0	2.0	1.1E5
240.0	25.0	9.6E3

The threshold of perception is reached above 200 V DC.
The "let go" current is never reached.
Lethal currents were never reached.

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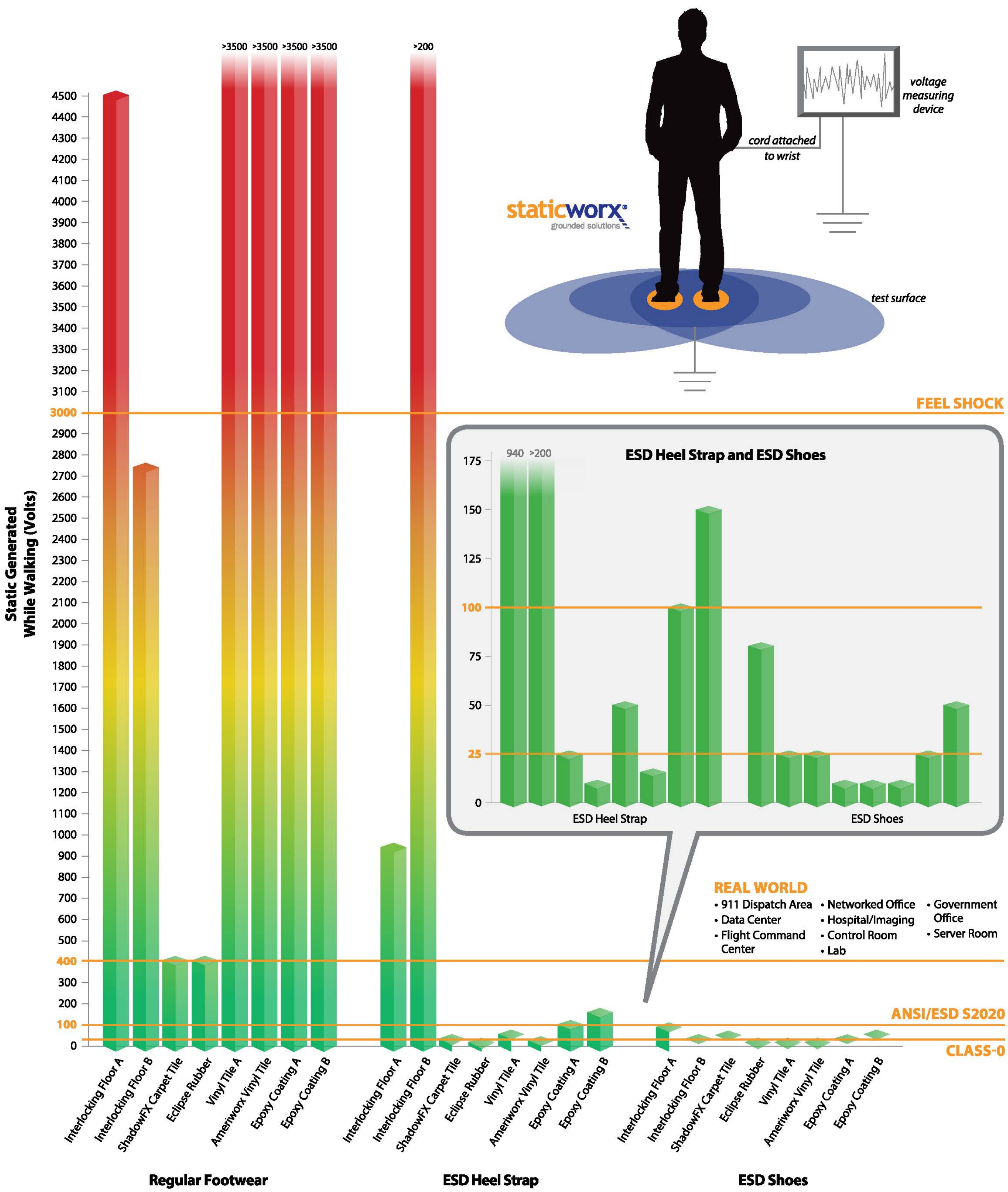
With Staticworx ESD flooring, there is no need to sacrifice safety for performance.

Body Voltage Generated with Different Footwear

Comparison Between Flooring Types



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