Footwear and flooring: charge generation in combination with a person as influenced by environmental moisture

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Abstract. It is well known that a person walking on a floor will liberate electrostatic charge. The amount of charge that can be accumulated on a person by walking is dependent on many factors that are also well understood. Among these factors is the electrical resistance between a person and ground. The electrical resistance of footwear, other clothing, a person’s skin resistance and the contact resistance between footwear and the floor impact the total resistance of the system. As important as measuring resistance may be as an evaluation method, it does not take into account triboelectric generation of charge. The recent revisions of ANSI/ESD S20.20[1] from the ESD Association and IEC61340-5-1[2] from IEC TC101 – Electrostatics, both include a dynamic walking test since experience in recent years has shown that resistance alone does not predict how a footwear and flooring system will actually perform. The USA group ASHRAE1, commissioned a study to evaluate electrostatic charge generation inside data centres as influenced by environmental moisture (relative and absolute humidity)[3][4]. The reason for this study is that past data centre operating guidelines have called for a very narrow range of temperature and humidity control, largely because of the anecdotal evidence that moderate to high RH impacts static electricity generation and accumulation. This results in a massive consumption of electricity to maintain a narrow window of temperature and environmental moisture. Broadening or eliminating humidity controls could result in a major saving of electricity and money.

1. Introduction
The ASHRAE study2 was conducted at the University of Missouri, Science and Technology, Rolla, MO, USA under the guidance of Dr David Pommerenke. Samples of flooring materials representing a broad range of materials available for flooring were obtained from manufacturers or purchased. The set included eighteen (18) different types of flooring ranging from conductive rubber to insulating high pressure laminates (HPL). Numerous conductive and dissipative range vinyl tiles were also included. A variety of footwear and shoe grounding devices were included in the study. The environmental

1 American Society of Heating, Refrigeration and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329 USA, +404/636-8400, www.ashrae.org
2 ASHRAE – 1499-RP, ibid
conditions ranged from dew points of -12°C to 18°C, which includes a relative humidity (Rh) range of 10% to 60%. An additional metric is the moisture content of the air. The moisture content of the air is measured in grains of water per pound of dry air. The range in this study was 8 to 83 grains of water/lb dry air. This value is directly related to the dew point and not relative humidity. The moisture content of the air was determined to be the overriding factor and much more important than temperature, at least within the environmental conditions which allow normal human activity.

2. Experimental procedures

Floor samples were installed on wood substrates approximately 1 meter square using the flooring manufacturers recommended installation procedures, including grounding techniques. Conditioning requirements according to ANSI/ESD STM97.1\(^3\) and 97.2\(^4\) were followed which involved maintaining each test condition for 72 hours prior to the actual testing. The walking voltage of a test subject was measured using a charge plate monitor (CPM) type device, data acquisition system and laptop computer with appropriate analysis software. ANSI/ESD STM97.2 describes a specific walking pattern so that there is good repeatability for each test subject. The walking pattern is shown in Figure 1 with an example of a walking voltage profile shown in Figure 2. Figures 3 and 4 show the 3 sigma (\(\sigma\)) calculated histograms for the standing and walking voltage respectively for the pattern in Figure 2.

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\(^3\) ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – *Floor Materials and Footwear – Resistance Measurement in Combination with a Person*, ESD Association, 7900 Turin Road, Building 3, Rome, NY 13440-2069, +315-339-6937, www.esda.org

\(^4\) ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – *Floor Materials and Footwear – Voltage Measurement in Combination with a Person*, ibid
Footwear and flooring walking voltage experiments were conducted in the various environmental conditions. Space is not available in this paper to show the results of many of the experiments. The walking voltage is calculated from the average of the peak voltages. After each walking cycle, a momentary pause allows the accumulated charge on a person to decay or relax at a rate that is basically controlled by the resistance of the test subject to ground. The average of the voltage at the pause between each walking cycle becomes the standing voltage.

3. Results

![Comparison of Peak Walking Voltage](chart1.png)

**Chart 1.** Comparison of three (3) types of footwear on three (3) types of floor at three (3) environmental moisture levels – Peak walking voltage.

In Chart 1, the moisture levels are shown in grains of water per pound of dry air. These are equivalent to 15%, 35% and 60% Rh at 23°C. These data points represent a summary of the range of results obtained in the study. From the left side of Chart 1, HPL is the type of floor material often used in raised flooring applications. For this study an insulating version was selected although there are some relatively conductive versions that perform much like conductive vinyl tile. The center set is conductive vinyl, a commonly used type of flooring in electronic manufacturing. The right set is a conductive rubber floor material also used in electronic manufacturing as well as in applications involving energetic materials. Three different sets of shoes are shown in Chart 1. The first is called a Deck shoe and is a type of casual shoe with a composite sole material that has high electrical resistance ($1.2 \times 10^{10} \Omega$ through the shoe while worn standing on a metal plate). The running shoe is a typical sports shoe with somewhat dissipative soles ($2 \times 10^8 \Omega$ at a moderate Rh). The conductive shoe is an ESD control rated safety shoe ($6 \times 10^6 \Omega$).

Study of Chart 1 provides some interesting information. Higher moisture content does not guarantee lower walking voltage. The triboelectric interaction of moisture between the floor and shoes varies the voltage levels, perhaps in unexpected ways. It is also important to note that the influence of the shoes is significant in controlling the walking voltage regardless of the floor material.

Chart 2 shows the standing voltage comparison for the walking voltage tests shown in Chart 1. Comparing Charts 1 and 2 gives some intuitive information about the ability of the test subject to decay their charge while on the floor sample. As is shown, moisture alone does not provide enough charge generation control or charge dissipation control. Both Charts have a line at 100 volts to
indicate the generally accepted level for electrostatic control in a factory setting. Data centers may allow a higher level since except for open panel service operations, the equipment is well protected as CE certification is normally required for all information technology equipment. The ASHRAE group has established 500 volts as the maximum level on personnel for service operations. Moving the line to 500 volts does not appreciably change the interpretation of the impact of moisture in the environment.

![Comparison of Standing Voltage](image)

**Chart 2.** Comparison of three (3) types of footwear on three (3) types of floor at three (3) environmental moisture levels – Standing Voltage (conductive shoes on conductive rubber near 0V)

4. **Conclusions**

As shown by study of the included Charts, it can be observed that while moisture in the environment has an impact and effect on the charging process and resulting accumulation of voltage on a test subject, there is little merit in using environmental moisture (absolute and relative humidity) to control static electricity without a controlled flooring and footwear system [5].

**References**

[1] ANSI/ESD S20.20 – *ESD Association Standard – For the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), ESD Association*

[2] IEC61340-5-1 *Electrostatics, Protection of electronic devices from electrostatic phenomena – General Requirements, International Electrotechnical Commission (IEC)*

[3] Hydeman M and Swenson D, 2010 *Humidity Controls for Data Centers: Are They Necessary?, ASHRAE Journal*

[4] Swenson D and Kinnear J, 2009 *The role of relative humidity and dew point on electrostatic charge and electrostatic discharge (ESD), The Green Grid, White Paper*

[5] Wan F, Hillstrom M, Stayer C, Swenson D and Pommerenke D, 2013 *ASHRAE Annual Conference, ASHRAE Transactions 2013, Volume 119, Part 2*