# Absolute humidity, relative humidity: which is more important in representing severity of electrostatic discharge

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Humidity is a very important factor in representing the severity of electrostatic discharge (ESD). Low humidity indicates high risk of ESD problems; high humidity indicates low risk of ESD problems. Both relative humidity and absolute humidity can represent the level of humidity: which one is more important? The reported measurement result shows that relative humidity is more important in the discharge phase. The qualitative analysis is given.

*Introduction:* For a long time, humidity has been considered as an important method to reduce the risk of electrostatic discharge (ESD) upsets and damage. The ESD occurrence rate can increase significantly as a result of a decrease of humidity [1]. Frei and Pommerenke [1] performed an ESD occurrence rate measurement in the University of Berlin; they used an ESD detection sensor to record the ESD events. At the lowest humidity level, in 1 hour the total ESD events number is used as the reference number. Then, all the other data are divided by the reference number and the relative frequency of occurrence was obtained. The humidity level is from 5 to 11 g/m$^3$ .The result is shown in Fig. 1; it shows how heavily the occurrence rate is influenced by absolute humidity. Thus, the American Society of Heating, Refrigerating and Air Conditioning Engineers gives guidelines of humidity to the data centre [2]. In the discharge phase of ESD, the discharge severity (peak current and rise time) is directly related to the arc length; a short arc length induces a large discharge current and a fast rise time. The typical value of the discharge current defined in IEC 61000-4-2 is 3.75 A/kV, and the rise time is 0.85 ns [3].

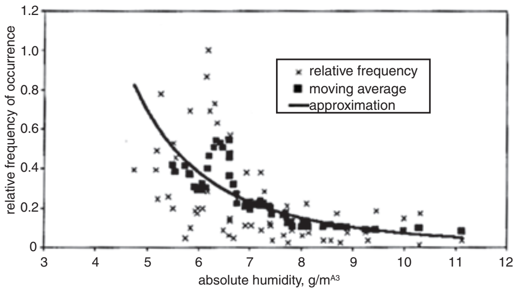


**Fig. 1** *ESD occurrence rate against absolute humidity [1]*

The physical process of the discharge phase is illustrated: when the voltage reaches the breakdown voltage, the initial electrons could initiate the breakdown. Humid air provides the initial electrons which induces a long arc length. Low humidity shortens the arc length, and increases the severity of ESD. However, both relative humidity (RH) and absolute humidity represent the humidity level. Which one is more important?

Relative humidity is the amount of moisture in the air compared to the maximum amount the air can 'hold' at that temperature. Relative humidity does not give an indication of how much vapour there actually is, but gives the ratio of the current actual vapour compared to the maximum vapour that the air can hold at saturation. Relative humidity can be calculated by using (1)

$$\text{relative humidity} = \frac{\text{actual vapour density}}{\text{saturation vapour density}} \times 100\% \quad (1)$$

Absolute humidity is the total amount of water vapour in a given volume and is typically expressed in g/m³. With high temperature, the capacity of air to hold moisture is high. With a certain level of absolute humidity, high temperature induces low-level relative humidity.

The question is relevant as the relative humidity will vary strongly within a data centre or any place with many types of equipment. It will be much lower at an air outlet of an air cooled rack where the local temperature is high. If absolute humidity would be the better measure to influence ESD risk, a simpler assessment of the data centre situation would be possible, but is that true? This Letter will give the answer through air discharge measurement.

*Test setup and measurement result:* To evaluate the effects of relative humidity and absolute humidity, two groups of measurements are conducted. In the first group, the relative humidity is kept the same (20% RH), but the temperatures are varied from 15 to 32°C. In the second group, the absolute humidity is kept the same $-$ 13.4 g/m$^3$, but the temperatures and relative humidity vary (26.7°C), 55% RH, and 32°C, 40% RH. For each environmental condition, the high-voltage supply is set to 5 kV, 20 discharges are performed. For each discharge, the current, transient field, arc length and approach speed are recorded. Before the test, the electrodes are slightly polished with 1000 grit paper and cleaned with alcohol. The test process can ensure that the surface influence on arc length, caused by changes from prior discharges is eliminated.

The test setup is shown in Fig. 2. The person holds a metallic discharge electrode in his hand. The person is charged to a high voltage (Noiseken ESS-S3011) via a 450 MΩ current limiting resistor. Then, as the person moves the electrode towards the current target (06–00067 A), a discharge occurs. The wall of a shielded cabinet is used as a ground plane with current and field sensor placed on it while the scope (Agilent DS0940) is placed inside. The discharge current is measured by the scope, and the transient fields are measured by field sensors (home-made sensor, with a bandwidth > 2 GHz); the arc length was measured by the high precise position sensor [3].

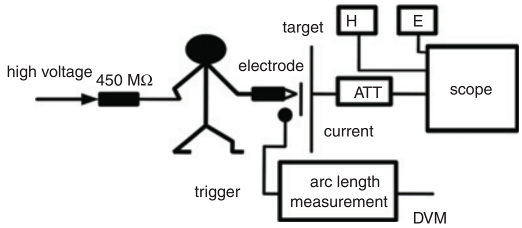


**Fig. 2** *Human metal discharge setup showing current measurement, electric and magnetic field sensors*

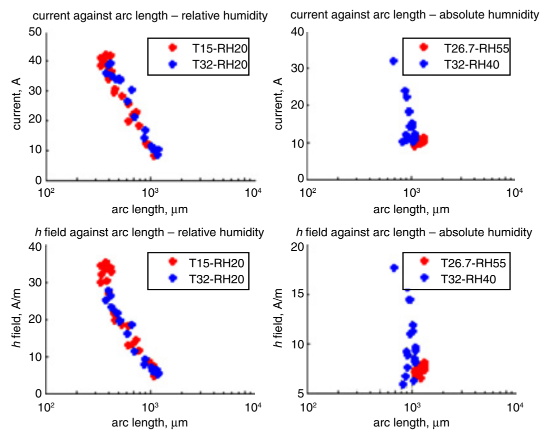


**Fig. 3** *Current and h field against arc length with 5 kV charge voltage*

Top left (current same – absolute humidity), top right (current same – relative humidity), bottom left (*h* field same – absolute humidity), bottom right (*h* field same – relative humidity)

With a 5 kV charge voltage, the discharge current and *h* field against arc length is shown in Fig. 3. With a slow approach speed, the Paschen's law is satisfied which is 1.1 mm for 5 kV charge voltage. This just verifies the correctness of the measurement setup. For faster approach speeds the combined effect of the approach speed and time lag leads to discharges over a shorter distance. Here, it is important to note that humidity has no direct effect on the arc development, but it influences the arc length. For a given arc length, the peak current is not a function of humidity. The current and rise time correlate well to the arc length. A long arc length induces a smaller peak current and a slower rise time. The ratio of the current and arc length is the same in all environmental conditions. This indicates that the humidity has no primary effect on the discharge current; however, certainly humidity has an indirect effect by influencing the average arc length via the time lag for the approaching electrodes [4].

The two cases on the right side of Fig. 3 are with the same absolute humidity. The ratio between current or $h$ field and arc length is the same so we do not see an influence by the humidity level. With the same approach speed, the discharge current range of 32°C, 40% RH is much larger than that of 26.7°C, 55% RH. The two environmental conditions on the left side of Fig. 3 are with the same relative humidity. With the same approach speed, although the absolute humidity is different (2.5 $g/m^3$ against 6.78 $g/m^3$), the discharge current range and $h$ field are similar. They both indicate that the relative humidity is more meaningful to represent the severity of ESD.

In a data centre, the absolute humidity is controlled very well, but the local temperature might be higher, which is caused by the operational electronic equipment. The high local temperature causes low relative humidity.

*Discussion:* If a human or an object is charged to the same voltage and discharged repeatedly, a large variation of current waveforms will be observed. The variations in the current are a result of differences in arc lengths. The arc length is determined by the approach speed, charge voltage and time lag. With the same charge voltage and the same approach speed, the time lag is the most important factor. A longer time lag induces a shorter arc length. Time lag is determined by the availability of seed electrons. These can be provided by field emission, by surface roughness enhanced field emissions and by detachment from water molecules. The surface condition is kept roughly the same for all the cases. With the same charge voltage, the humidity is the most important factor. Humid air has a strong effect in reducing the time lag, most probably due to electron detachment from the water molecules on the cathode surface. As the relative humidity indicates the moisture on the cathode surface, it is the more important component when compared to absolute humidity. The measurement results with same relative humidity, but different absolute humidity, support this conclusion.

*Conclusion:* Through air discharge measurement, the parameters that can represent the severity of ESD are recorded; the results show that the humidity does not have a direct influence on ESD, but the humid air provides the initial electrons which induces fast breakdown. As the relative humidity indicates the moisture on the cathode surface, it is the more important factor when compared with absolute humidity.

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One or more of the Figures in this Letter are available in colour online.

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## References

1 Frei, S., and Pommerenke, D.: 'A study of the impulsive field occurrence rate and intensity'. IEEE 1997 Int. Symp. Electromagnetic Compatibility, Austin, TX, USA, August 1997, pp. 507–512
2 Hydeman, M.: 'Implications of current thermal guidelines for data center energy use', *ASHRAE J.*, 2010, **August 2010**, pp. 30–41
3 Chundru, R., Pommerenke, D., Wang, K., Van Doren, T., Centola, F.P., and Huang, J.: 'Characterization of human metal ESD reference discharge event and correlation of generator parameters to failure levels – Part I: Reference event', *IEEE Trans. Electromagn. Compat.*, 2004, **46**, pp. 498–504
4 Pommerenke, D.: 'On the influence of the speed of approach, humidity and arc length on ESD breakdown' (ESD Forum, Grainau, 1993) pp. 103–111