Measuring the Right Layer: Why Conforming Two-Layer Worksurface Mats Fail Incoming Inspection

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Disclosure: The author's company manufactures ESD worksurface matting. The samples described here were taken from the author's own production. No product, brand or commercial claim is made in this article.

Abstract

Two-layer rubber worksurface mats combine a static-dissipative top surface with a conductive bottom layer. When an incoming inspection specification applies a single resistance window, commonly 1×10^6 to 1×10^9 Ω, to every surface of the mat, the conductive bottom layer is rejected even though the product conforms. This article reports point-to-point and resistance-to-ground measurements on two samples of a two-layer mat, taken with a calibrated megohmmeter, with temperature and humidity recorded for every reading. The dissipative top surfaces measured 2.26×10^6 to 4.18×10^7 Ω point to point. The conductive bottom layers measured 2.50×10^4 to 2.22×10^5 Ω, and resistance to ground from the top surface measured 1.64×10^7 to 2.46×10^7 Ω. Applied to the bottom layer, a single 10^6 to 10^9 Ω window fails 8 of 8 readings on mats that meet the ANSI/ESD S20.20 worksurface requirements. The article also reports how the return path changed resistance-to-ground readings, and proposes specification wording that avoids this kind of false rejection.

1. Introduction

Incoming inspection of ESD worksurfaces is often done with a megohmmeter and a pair of weighted electrodes, against a resistance window written into a purchasing or quality document. The method is sound. The problem starts when the specification does not say which surface is to be measured.

Two-layer mats are built from two compounds with different jobs. The top surface, where ESD-sensitive items are placed, is static dissipative. The bottom layer is conductive and carries charge laterally to the ground snap. Each layer has its own design range. An inspector who turns the mat over, or tests a cut edge, measures a surface that was never intended to meet the top-surface range.

This article documents the effect with measured data and relates it to the requirements in ANSI/ESD S20.20.

2. What the Standard Requires

ANSI/ESD S20.20-2014, Table 3, gives the following for worksurfaces:

Table 1. Worksurface requirements in ANSI/ESD S20.20-2014

Purpose	Test method	Required limit
Product qualification	ANSI/ESD S4.1	Point-to-point < 1×10^9 Ω; point-to-groundable point < 1×10^9 Ω
Product qualification	ANSI/ESD STM4.2	< 200 V

(alternative)		
Compliance verification	ESD TR53 (worksurface)	Resistance to ground < 1×10^9 Ω

Two footnotes matter here. Footnote 9 defines a worksurface as the surface on which unprotected ESD-sensitive items are placed. Footnote 10 notes that a lower limit of 1×10^6 Ω should be considered where charged-device-model (CDM) damage is a risk. The standard does not require a 1×10^6 Ω lower limit. Where users adopt one, it is an organisational choice, and by the definition in footnote 9 it applies to the top surface.

Read together, the two footnotes mean that a lower limit set for CDM reasons has no meaning for the bottom layer of a two-layer mat. That layer is not a worksurface in the sense of the standard.

3. Two-Layer Construction

The mats tested are calendered rubber with two co-vulcanised layers:

- **Top layer (dissipative), design range 1×10^6 to 1×10^9 Ω.** It limits the rate at which charge leaves a device placed on the surface.
- **Bottom layer (conductive), design range 1×10^4 to 1×10^6 Ω.** It spreads charge across the mat to the ground snap, so that resistance to ground stays low however far the point of contact is from the snap.

Total thickness 2 mm; top layer 0.5 mm; bottom layer 1.5 mm. The ground snap is a metal stud pressed through the mat into the conductive layer.

4. Test Method

Table 2. Instrument, set-up and samples

Item	Detail
Instrument	ACL Staticide Model 800 megohmmeter with built-in temperature and humidity sensing
Calibration	Calibrated 19 Aug 2026, certificate 1245/617 (ACL Inc.), serial R01172234; 10 V range verified 10^3 to 10^8 Ω, 100 V range 10^6 to 10^{11} Ω, all points within ±10 %
Electrodes	Two cylindrical 5 lb (2.27 kg) weighted electrodes, contact diameter 65 mm, conductive rubber contact
Point-to-point spacing	250 mm, centre to centre
Test voltage	10 V range for all readings reported in Tables 3 to 8
Reading	Press-and-hold reading after 15 s electrification
Support	Sample laid flat on a white-surfaced wooden bench top
Resistance to ground	One electrode on the top surface; the second External Electrodes lead clipped directly to the mat's ground snap
Conditions	Ambient laboratory air, recorded per reading by the instrument (see tables)
Samples	Sample A: green dissipative top, black conductive bottom, 400 ×

	450 mm, tested 19 Oct 2026. Sample B: grey dissipative top, black conductive bottom, 320 × 320 mm, tested 3 Nov 2026.

The samples were not pre-conditioned at the low-humidity condition in ANSI/ESD S4.1. All readings were taken at ambient humidity, which is recorded with each value. See Section 7.

5. Results

5.1 Top surface, point to point (Sample A)

Table 3. Top surface, point to point. Conditions: 65.4 to 65.7 %RH, 29.0 to 29.8 °C

ID	Reading (Ω)
T01	1.44×10^7
T02	2.26×10^6
T03	1.98×10^7
T04	2.00×10^7
T05	3.19×10^7
T06	2.00×10^7
T07	1.98×10^7
T08	4.18×10^7
T09	4.15×10^7

Range 2.26×10^6 to 4.18×10^7 Ω; median 2.00×10^7 Ω. All readings are below 1×10^9 Ω and within the 10^6 to 10^9 Ω design range.

5.2 Bottom layer, point to point (Sample A)

Table 4. Bottom layer, point to point. Conditions: 58.1 to 58.9 %RH, 27.9 °C

ID	Reading (Ω)
B01	2.63×10^4
B02	2.50×10^4
B03	4.95×10^4

Range 2.50×10^4 to 4.95×10^4 Ω. All readings are within the 10^4 to 10^6 Ω design range for the conductive layer.

5.3 Resistance to ground from the top surface (Sample A)

Table 5. Resistance to ground, return lead clipped directly to the ground snap. Conditions: 58.7 to 58.9 %RH, 28.0 °C

ID	Electrode position	Reading (Ω)
G01	Adjacent to ground snap	1.64×10^7
G02	Corner farthest from snap	1.99×10^7
G03	Corner farthest from snap (repeat)	1.99×10^7

All readings are below the 1×10^9 Ω limit by a factor of about 50.

5.4 Sample B

Sample B was tested in a separate session with the same instrument, electrodes and connections. Its ground snap is at one corner.

Table 6. Sample B, top surface, point to point. Conditions: 64.0 to 64.6 %RH, 27.3 °C

ID	Reading (Ω)
BT01	3.39×10^{7}
BT02	3.24×10^{7}
BT03	3.31×10^{7}

Table 7. Sample B, bottom layer, point to point. Conditions: 64.5 to 65.2 %RH, 27.3 to 27.4 °C

ID	Electrode position	Reading (Ω)
BB01	Across the sample	2.22×10^{5}
BB02	As BB01 (repeat)	2.22×10^{5}
BB03	Diagonal	2.13×10^{5}
BB04	Opposite diagonal	2.07×10^{5}
BB05	Opposite diagonal (repeat)	2.08×10^{5}

Table 8. Sample B, resistance to ground, return lead clipped directly to the ground snap. Conditions: 62.3 to 62.7 %RH, 27.1 to 27.2 °C

ID	Electrode position	Reading (Ω)
BG01	Corner farthest from snap	2.31×10^{7}
BG02	Near the farthest corner	2.38×10^{7}
BG03	Corner on the same side as the snap	2.41×10^{7}
BG04	Other corner on the same side as the snap	2.46×10^{7}

Sample B repeats the pattern of Sample A. The top surface (3.24×10^{7} to 3.39×10^{7} Ω) is within the 10^{6} to 10^{9} Ω design range. The bottom layer (2.07×10^{5} to 2.22×10^{5} Ω) is within the 10^{4} to 10^{6} Ω range for the conductive layer. Resistance to ground (2.31×10^{7} to 2.46×10^{7} Ω) is below 1×10^{9} Ω by a factor of about 40.

6. Discussion

6.1 The false failure

Suppose an incoming inspection specification reads "1×10^{6} to 1×10^{9} Ω, point to point" and does not name a surface. An inspector who tests the top surface passes both mats, 12 of 12 readings. An inspector who tests the bottom layer fails them, 8 of 8 readings: values 20 to 40 times below the lower limit on Sample A and about 5 times below it on Sample B. The mats are the same and conform to their design, and S20.20 has no requirement that the bottom layer could fail.

The failure here comes from the specification, not the product. It tends to appear when a mat is supplied rolled or stacked with the conductive side out, when an inspector tests a cut edge, or when the two sides are hard to tell apart by colour.

6.2 What resistance to ground shows about the conductive layer

On Sample A, moving the electrode from beside the snap to the farthest corner raised resistance to ground only from 1.64×10^7 to 1.99×10^7 Ω. On Sample B, four corner positions gave 2.31×10^7 to 2.46×10^7 Ω, a spread of about 6 %. On both samples, resistance to ground was close to the top-surface point-to-point values (median 2.00×10^7 Ω on Sample A; 3.24×10^7 to 3.39×10^7 Ω on Sample B).

This is what a two-layer construction should produce. Current crosses the dissipative layer once, at the electrode, and then travels through a conductive layer whose own resistance is two to three orders of magnitude lower. Distance to the snap therefore has little effect. On a single-layer dissipative mat, resistance to ground would rise more steeply with distance.

The low bottom-layer readings in Sections 5.2 and 5.4 are therefore the reason resistance to ground stays uniform across the mat. Rejecting the mat for those readings rejects the feature that makes it work.

6.3 Sensitivity to the return path

In an earlier set of resistance-to-ground readings on Sample A, the return lead ran from the ground snap through a wrist-strap ground terminal block before reaching the meter. These readings were 6.35×10^8 to 9.67×10^8 Ω (four readings on the 100 V range, 55.6 to 56.4 %RH, 27.1 °C). That is 30 to 60 times higher than with the lead clipped directly to the snap. The cause was not isolated in this work.

The practical point holds either way. A reading that includes ground hardware measures the hardware as well as the mat. For product qualification, the return lead should be clipped to the snap. For compliance verification under TR53, where the full path to ground is the object, the hardware is part of what is being verified and should be recorded as such.

6.4 Display units

The instrument used here prints "ohms/sq" beside the reading. A note beside the external electrode sockets states that the value is in ohms when external electrodes are used. Inspectors who copy the display label into a record report surface resistivity, a different quantity, and comparisons against a specification in ohms then go wrong. The test record should state the quantity measured, not the label on the display.

7. Limitations

- Readings were taken at ambient humidity (55.6 to 65.7 %RH), not after the low-humidity conditioning in ANSI/ESD S4.1. Resistance of dissipative materials generally rises as humidity falls, so the top-surface and resistance-to-ground values here should not be read as low-humidity performance.
- On Sample A, the bottom-layer and resistance-to-ground readings were taken in a later session, at about 7 %RH lower humidity than the top-surface readings. Sample B was tested on a different day, within the same humidity range.
- The samples rested on a wooden bench top whose own resistance was not measured. Any leakage path through the bench would act in parallel with the mat and could only lower the readings, not raise them.
- The data come from two samples from one production source. The article shows a measurement effect; it is not a statistical characterisation of the product.

8. Recommendations for Incoming Inspection Specifications

1. **Name the surface.** For example: "Point-to-point and resistance-to-ground measurements shall be made on the surface on which ESD-sensitive items are placed."
2. **Give the bottom layer its own range, or leave it out.** If construction is to be verified, state the conductive-layer range separately, for example 1×10^4 to 1×10^6 Ω. If not, exclude the bottom layer from acceptance testing.
3. **State whether a lower limit applies and why.** S20.20 requires only $< 1 \times 10^9$ Ω. A 1×10^6 Ω lower limit is a CDM-driven choice and should be written as such, for the top surface.
4. **Define the return path for resistance to ground.** For product acceptance, clip directly to the mat's ground snap. Record any additional hardware.
5. **Record conditions and the quantity measured.** Temperature, relative humidity, test voltage, electrode spacing, and the unit (Ω, not Ω/sq) with every reading.

9. Conclusion

A two-layer worksurface mat has two surfaces with two design ranges, and only one of them is a worksurface in the sense of ANSI/ESD S20.20. Measured on the correct surface, both mats in this study met the S20.20 requirements with a margin of about 40 to 60 times on resistance to ground. Measured on the wrong surface against an unqualified 10^6 to 10^9 Ω window, the same mats failed every reading. Naming the surface and the return path in the specification prevents this.

References

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About the Author

Rachel Zhong is an ESD engineer at HORBEST Tech Co., Ltd., Shenzhen, with 29 years' experience in static-control materials, including worksurface and flooring compounds, test methods and customer incoming-inspection support. A step-by-step version of the test procedure, with photographs, is available at https://esdbest.com/how-to-test-esd-mat/. Contact: sales2@esdbest.com.