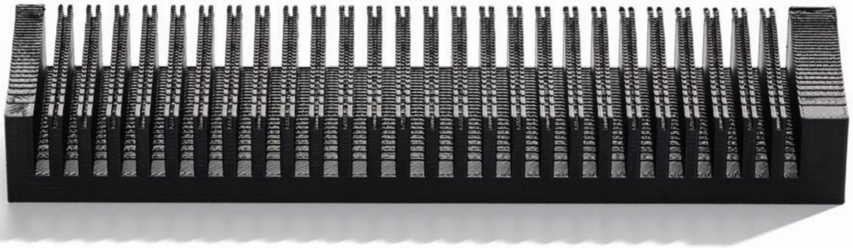
Electrical Properties of Antero 840CN03



White Paper

Electrical Properties of Antero 840CN03

Antero™ 840CN03 is a Stratasys proprietary polyetherketoneketone (PEKK) based material and part of the polyaryletherketone (PAEK) family. It is a semi-crystalline, high-performance thermoplastic resin known for its strength, high temperature tolerance and excellent chemical-resistance properties.

Antero 840CN03 is an ESD (electrostatic dissipative) compliant material that can dissipate current through the polymer matrix to prevent static discharge in 3D printed parts made with this material. Experimentation to characterize its electrical properties has shown that most part geometries perform within the resistance range of 103 to 109 ohms, which is compliant with ESD requirements for most industries.

The purpose of this electrical property evaluation was to characterize typical ESD performance of different 3D printed geometries using standard print conditions. The part suite tested represents common geometries to illustrate expected results. Actual part performance may vary and should be evaluated on a case by case basis.

Figure 1. PRS resistance meter with concentric circle probe.

Methods:

The methods and specifications for testing the material and subsequent parts are laid out in:

- **ANSI ESD S20.20**—Standard for the Development of an ESD Control Program
- **ANSI ESD S11.11**—Surface Resistance Measurement of Static Dissipative Planar Materials
- **ANSI ESD STM11.12**—Volume Resistance Measurement of Static Dissipative Planar Materials
- **ASTM D257**—Standard Test Methods for DC Resistance or Conductance of Insulating Materials
- **ASTM D4496**—Standard Test Methods for DC Resistance or Conductance of Moderately Conductive Materials

The equipment used during testing was the Prostat PRS-801 Resistance System Set with a PRS-911 Concentric Ring Probe Set (Figure 1), in compliance with ANSI ESD specifications. Additional external testing was also conducted using the Silver paint method outlined in the above ASTMs.

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To characterize the performance of the material an ESD part suite (Table 1, Figure 2) was developed to look at various build orientations, printer positions, infill, and challenging geometries to illustrate the performance variation customers might encounter in their design of countless part types.

Part Suite
Description
Plate, flat (XY)
Plate, edge (ZX) **(Figure 2, B)**
Plate, 45 degree **(Figure 2, A)**
Plate, flat raised 1”
Plate, flat raised 2“
Plate, flat raised 4”
Whole platen test, plate flat (XY)
Thin (0.050” wall) cylinder XZ **(Figure 2, C)**
Thin (0.050” wall) cylinder ZX **(Figure 2, C)**
Thin (0.10” wall) cylinder XZ
Thin (0.10” wall) cylinder ZX
Thick (0.20” wall) cylinder XZ **(Figure 2, D)**
Thick (0.20” wall) cylinder ZX **(Figure 2, D)**

Table 1. ESD test part suite.

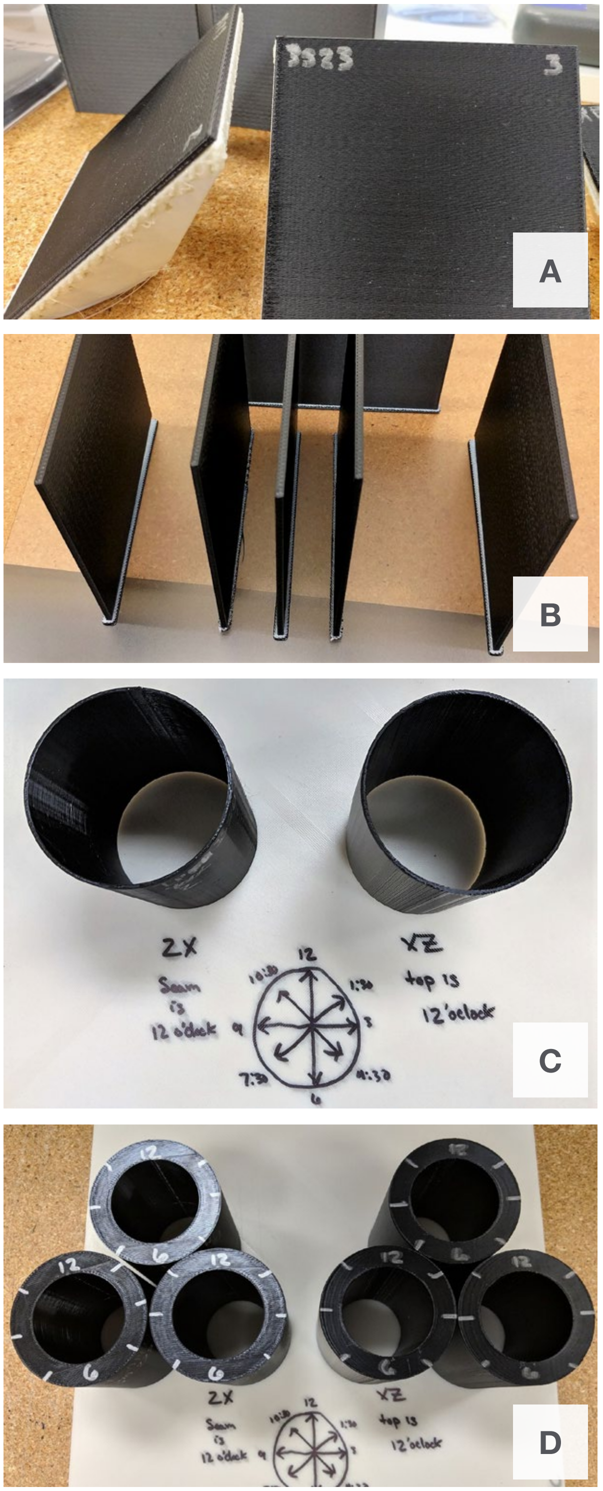

Figure 2. Examples of test parts for ESD suite.
A) plate, 45 degrees. B) plate, edge (ZX). C) thin (0.05 wall) cylinder.
D) thick (0.20 wall) cylinder.

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Parts were all printed using hardened F900™ print systems, utilizing multiple printers and multiple lots. For the sake of consistency, all sample packs were standardized to three test specimens, positioned in a straight line in the center of the build envelope (Figure 3). These specimens were tested as a set and values were reported as a mean of each set.

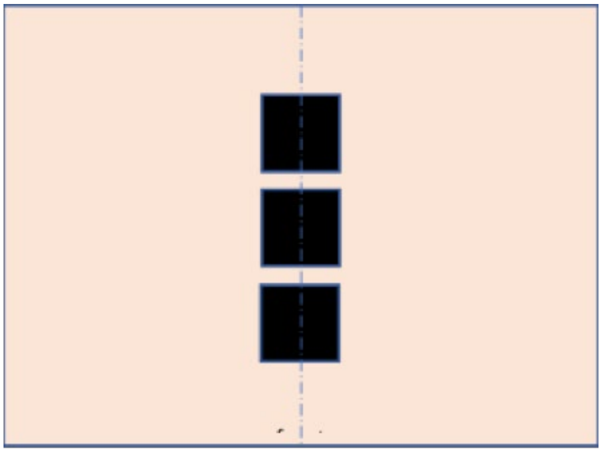


Figure 3. Standard pack configuration.

A baseline was established using 4” x 4” x 0.1” flat (XY), on-edge (ZX), and 45° plaques. These plaques were included in the part suite and used to establish a baseline performance for the material.

Additional variables evaluated as part of the study include (parts detailed in Table 1):

- Distance from build plate
- Position of parts on build plate
- Thickness and infill of parts
- Thickness and curved surfaces

Resistance was measured, then converted into resistivity for the report and calculated as follows:

Volume Resistivity = ρv (Ω·cm)

$$\rho_v = R_v \frac{A}{t}$$

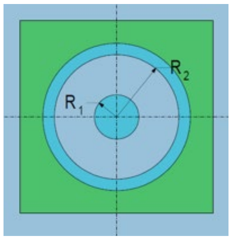
R_v = volume resistance, Ω,
A = area of the electrodes, cm^2, and
t = distance between the electrodes, cm.

Surface Resistivity in Ω (per square) ρs

$$\rho_s = R_s (W/L)$$

R_s = surface resistance, Ω
L = length of the specimen between electrodes, and
W = width of the specimen.

For the Prostat system



$$\rho_s = R_s \frac{2\pi}{\ln\left(\frac{R_2}{R_1}\right)}$$

ρv=(6.9/t) x Rv

t = thickness (cm)

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Test results show that neither part orientation, height off build plate, part thickness, raster infill, or position in the printer significantly affect the plaques' resistance. All of the resistance values are within the same order of magnitude (E5), with little fluctuation between plaques. As values are corrected for resistivity (surface = ohms/square, volume = ohms-cm), the values increase by roughly one order of magnitude (figure 9).

Stratasys tested cylindrical samples using the same methods; evaluating thin (0.05"), medium (0.1"), and thick (0.2") walled cylinders to determine if there is correlation between wall thickness and electrical properties in curved surfaces.
Each tube was tested at four points using the face of a clock to identify position (12/3/6/9 o'clock), with the horizontally built cylinders having 12:00 position as the top of the print, and vertically built cylinders having the 12:00 positions as the seam (Figure 2, C and D).

Test results were then validated by an outside electrical testing laboratory.

Figures 4 through 6 show that variation in part orientation (Figure 4), height off platen (Figure 5), and position of part in printer (Figure 6) have little to no effect on the electrical properties of the subsequent parts. This highlights the stability of the material and printing process to achieve consistent ESD performance.

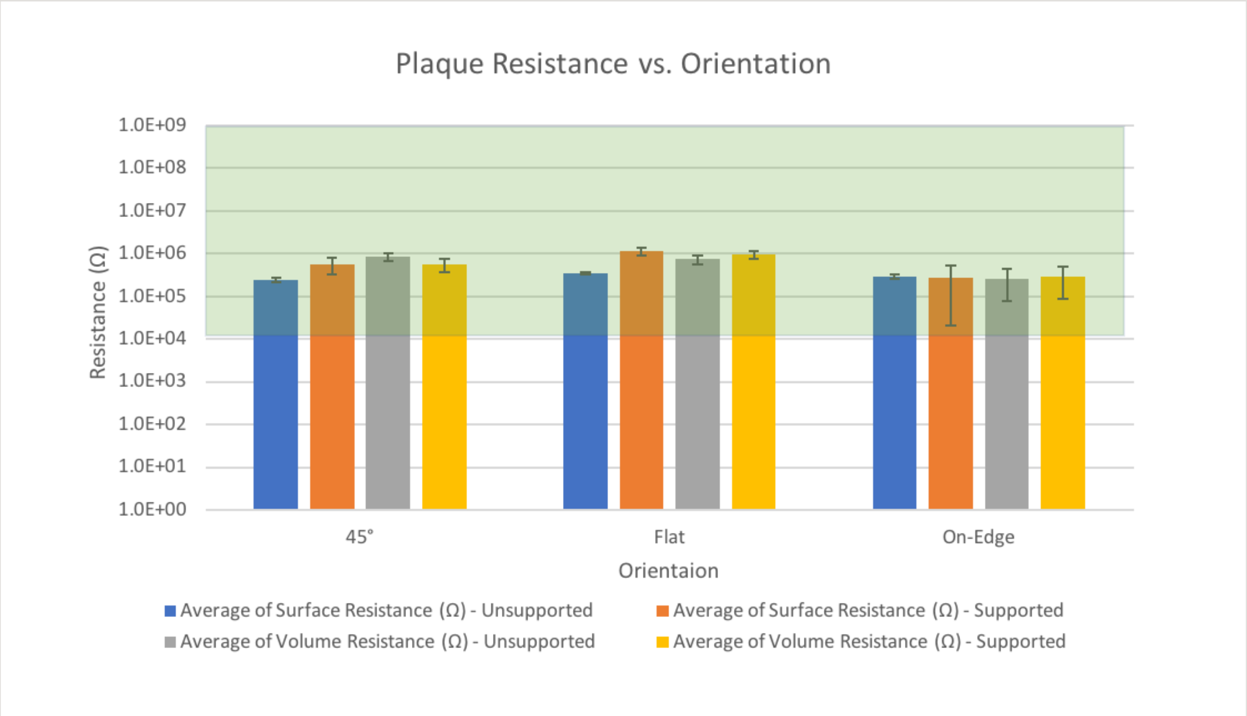

Figure 4. 4 x 4 x 0.1 inch plaque resistance in various build orientations.

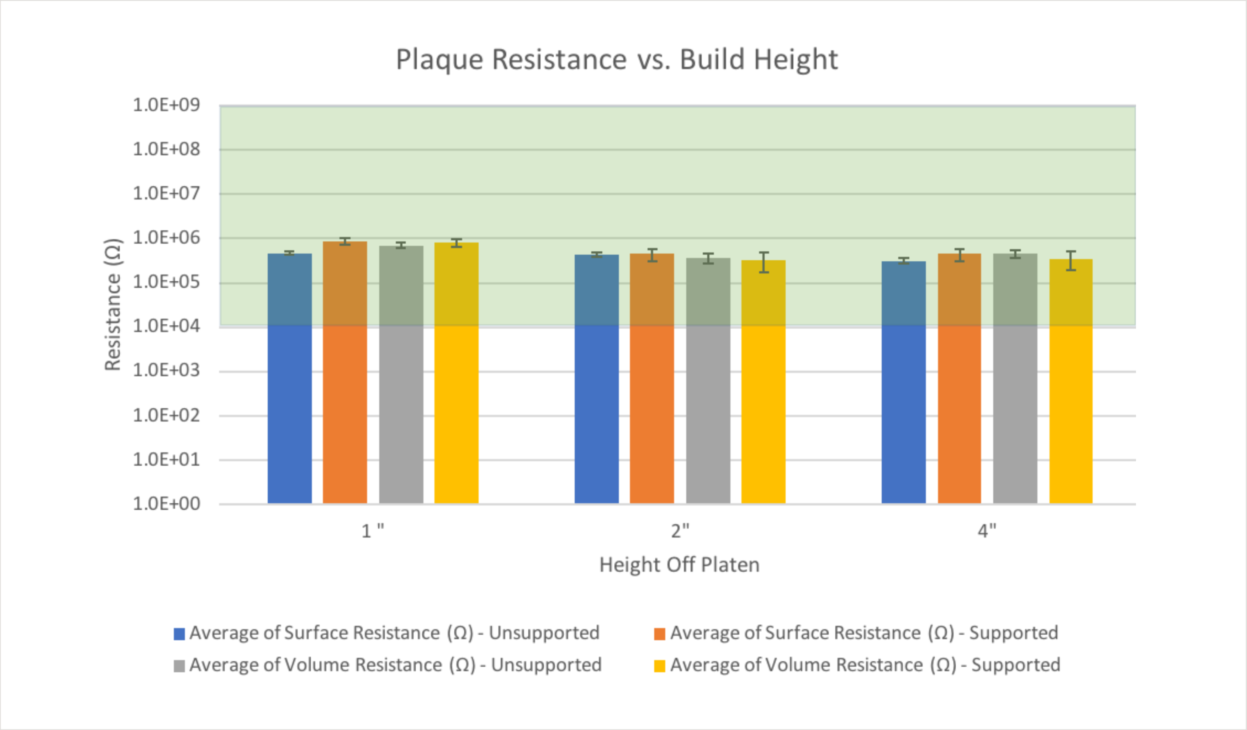

Figure 5. Plaque height vs. resistance values.

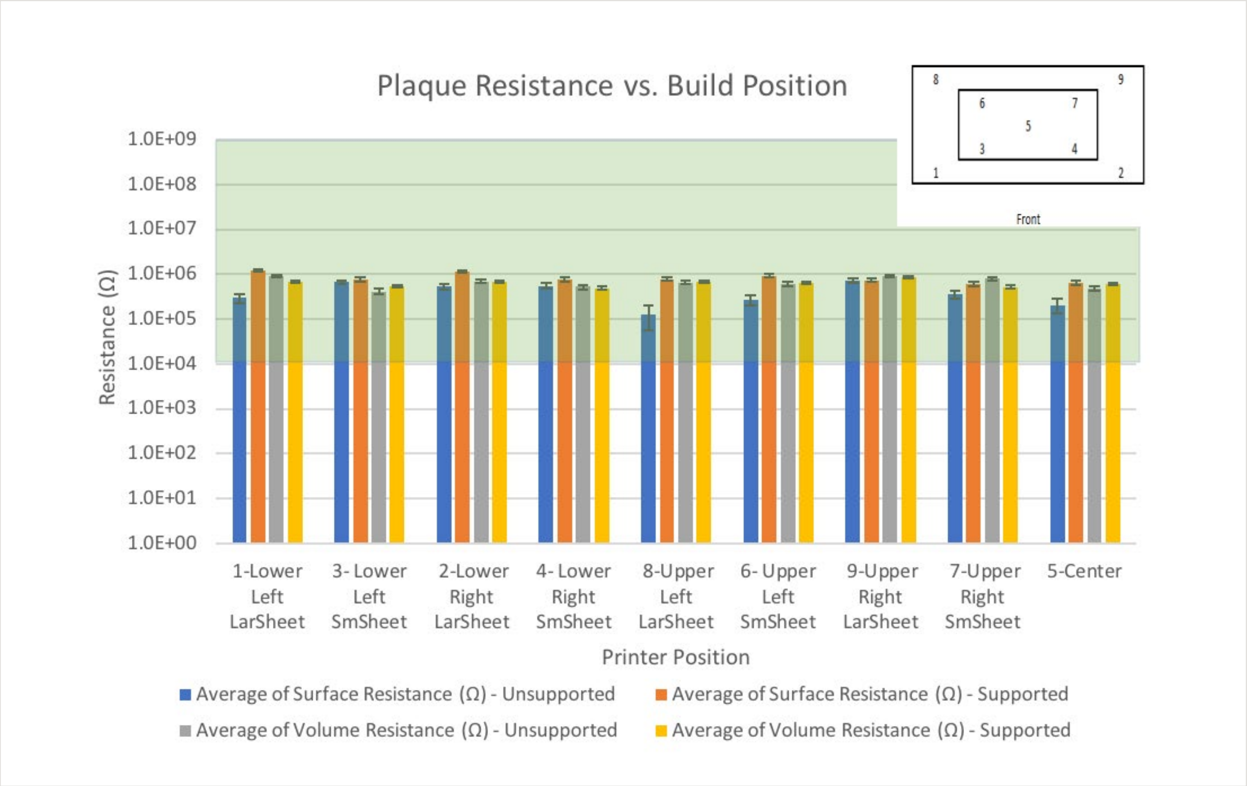

Figure 6. Plaque build position vs. part resistance.

Figure 7 and Figure 8 show that part thickness and infill style also have little effect on the electrical conductance through the part. The figures also show the difference between resistance and resistivity and how that may change based on the thickness of the parts being measured.

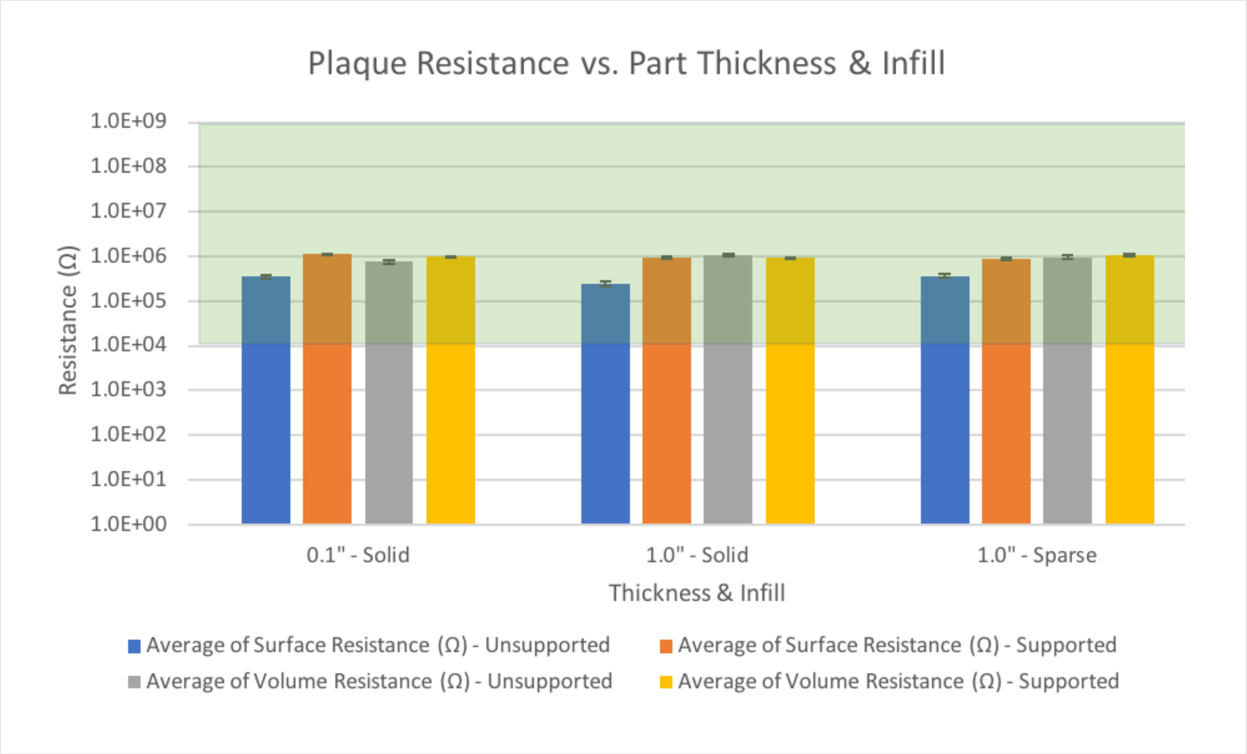

Figure 7. Resistance variation based on part thickness and interior raster fill.

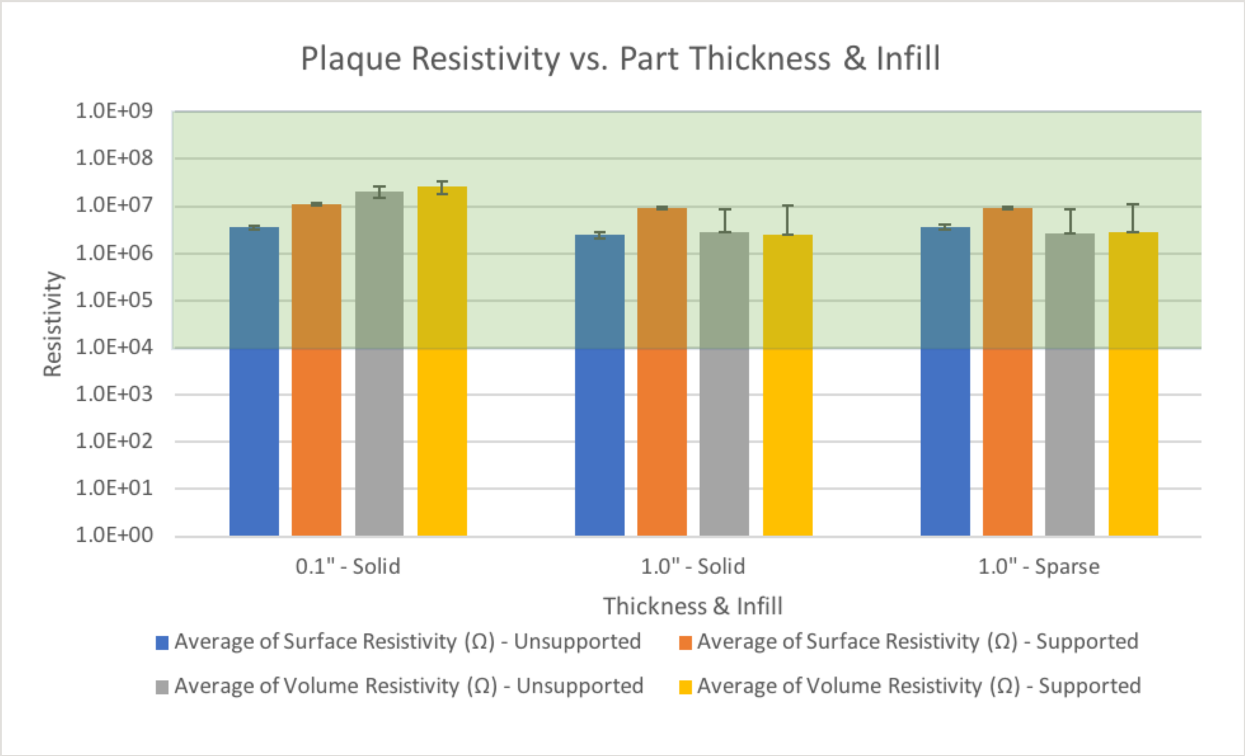

Figure 8. Resistivity variation based on part thickness and interior raster fill.

Figure 9 and Figure 10 showcase the electrical results for hollow cylinders when printed on their sides vs. upright.

The surface resistance of the cylinders in Figure 9 illustrates that the upright (ZX) orientation is much more consistent than the on-side (XZ) specimens. This is due to the stair-step affect that we see in the thinner walled cylinders which inhibits the propagation of current through the part. As wall thickness increases the resistance stabilizes and decreases.

Figure 10 exhibits the same phenomena with volume resistance. The thinner walled samples show more variable electrical resistance then the thicker samples. The anomalous increase in in the 0.1” ZX samples was due to one of the five sets average being two orders of magnitude higher. This outlier set had a significant effect on the average values due to the exponential nature of the measurements.

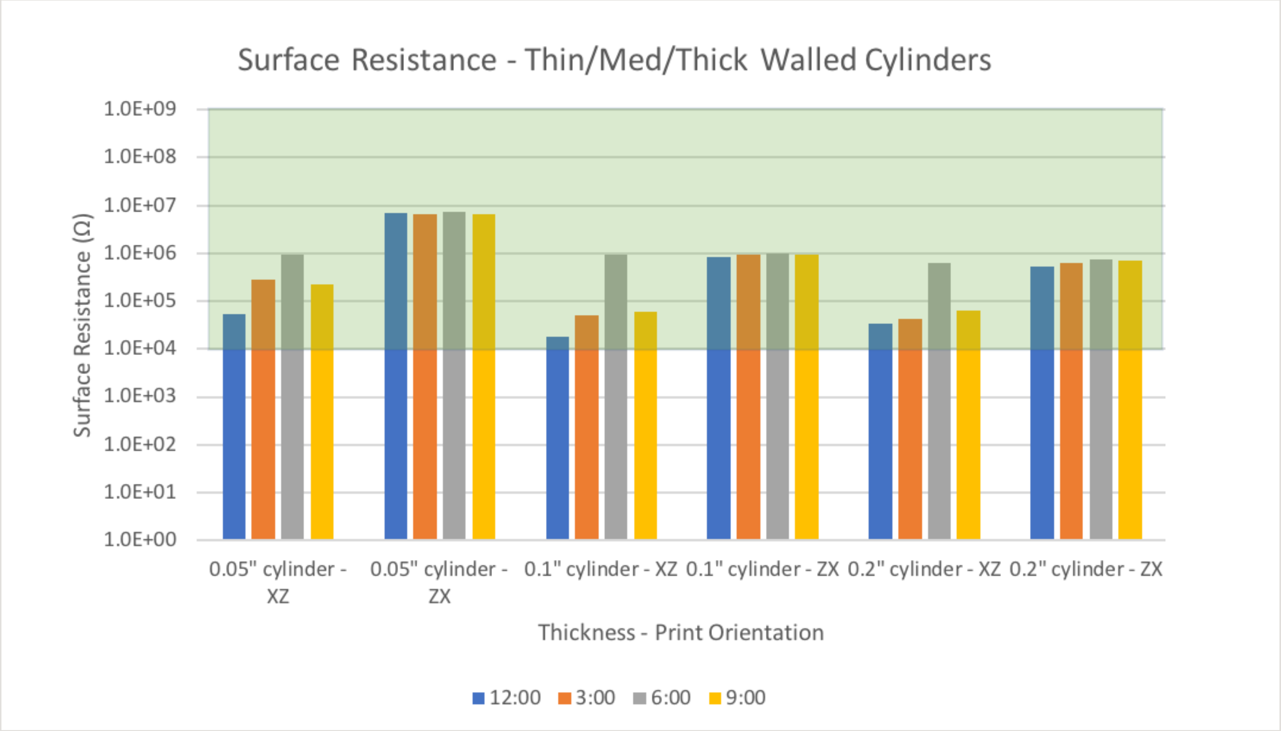

Figure 9. Surface resistance of hollow cylinders with respect to wall thickness and build orientation.

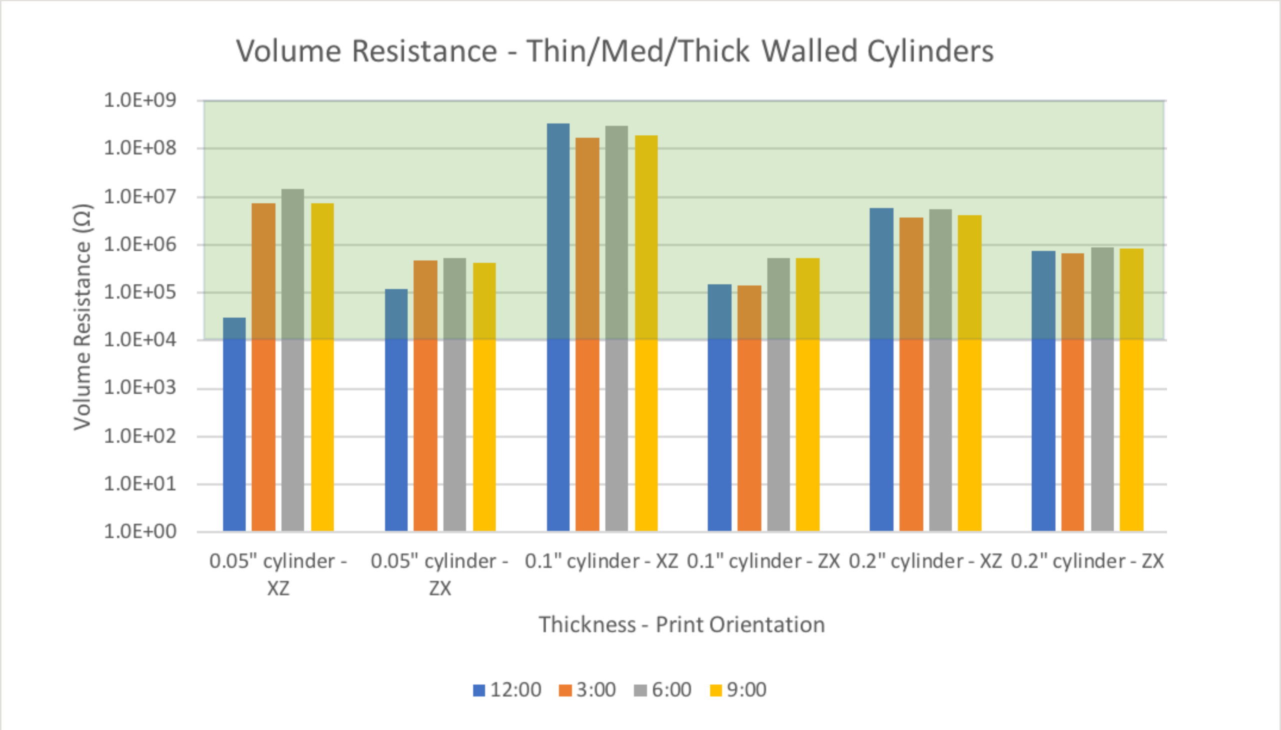

Figure 10. Volume resistance of hollow cylinders with respect to wall thickness and build orientation.

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Silver Paint Results:

Additional samples were sent to an independent external laboratory to determine resistivity values using other equipment and possible methods.

Using ASTM D4496, the outside laboratory prepared the samples with silver paint electrodes and tested the specimens using a multimeter.

The results of that testing showed resistivity values less than what was tested using the PRS meter.

A reduction of resistivity was also seen when using silver paint on the surface of the specimens and testing using the PRS probe.

The conclusion based on these results is that the contact resistance between the probes of various test equipment and methods plays a significant role in the measured resistance/resistivity of the part.

	Surface Resistivity (ohms/square)	Volume Resistivity (ohms-cm)
ASTM D4496 - Silver paint electrodes - 1” x 4” x 0.1” coupons - External Lab		
On-edge (XZ)	1.6E+03	4.0E+02
Flat (XY)	6.9E+03	1.8E+03
Upright (ZX)	>E7	>E7
ASTM D4496 - Silver paint electrodes - 1” x 4” x 0.1” coupons - Stratasys Lab		
On-edge (XZ)	3.3E+03	2.5E+02
Flat (XY)	1.5E+04	7.9E+02
Upright (ZX)	>E7	>E7
ASTM D257 - PRS Meter - 1” x 4” x 0.1” coupons - Unpainted		
On-edge (XZ)	5.6E+05	6.2E+06
Flat (XY)	1.3E+06	1.5E+07
Upright (ZX)	4.6E+07	1.2E+07
ASTM D257 - PRS Meter - 1” x 4” x 0.1” coupons - Ag Painted		
On-edge (XZ)	5.6E+03	4.2E+05
Flat (XY)	1.8E+04	1.2E+06
Upright (ZX)	4.1E+05	9.6E+05

Table 2: Test method comparison showing variation in painted electrodes and multimeter vs. concentric ring probe.
Note: Multi-meter has a E7 limit.

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Conclusion:

For Antero 840CN03, there is no significant variability in electrical resistance based on part orientation, height off build plate, position in printer, thickness or infill of printed parts. Although there is a slight difference between supported and unsupported faces with supported faces being slightly more resistive, overall, the variation is not significant, and the electrical isotropy of printed parts is robust.

Anomalies in thin walled cylinders can be mitigated through print orientation or by increasing wall thickness. Customers should be aware that varying geometries may exhibit electrical percolation through the parts in unexpected ways and may not be fully covered in this document.

Variations in electrical property measurements may occur based on the equipment and test methods used. Customers are urged to define the most applicable test method and equipment that will give the most appropriate results based on specific real-world applications.

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