TECHINHERIT / TECHNICAL NOTE 01

Why Antistatic Injection Molded Parts Fail Resistance Tests

A practical guide to separating material-network, molding, conditioning and measurement effects in finished plastic components.

A passing pellet or laboratory plaque does not qualify a molded part. Specify the electrical property, test geometry, conditioning and end-use location first; then compare equivalent measurements across material lots, cavities and production time.

Executive summary

Resistance varies because the electrical path is a product of formulation and the molded microstructure. Conductive carbon networks can change sharply near the percolation threshold; flow can redistribute or orient filler across skin and core. Migratory antistats depend on surface enrichment and ambient moisture, while non-migrating dissipative polymers require a continuous compatible phase. These are distinct mechanisms and should not be diagnosed with one generic “antistatic” label.

A second class of “failures” comes from the test itself: surface resistance is not surface resistivity, contact geometry differs on ribs and curves, humidity and electrification time affect readings, and a standard intended for insulation may be outside its stated range for a conductive compound.

Fast diagnostic sequence

01 Confirm the claim	02 Reproduce the test	03 Localize the change
Define target range, property, surface/volume path, orientation, use condition and acceptance rule.	Use one method, fixture, voltage, dwell, conditioning, cleaning rule and calibrated meter.	Map locations and cavities; compare flat plaque with production part, dry vs conditioned, and surface vs through-thickness.

Scope: engineering decision support. This note gives no universal pass band or unverified TechInherit test result. Product acceptance limits must come from the customer application, the applicable standard and a validated measurement plan.

1 Choose the physical mechanism before changing the process

Carbon black, carbon fiber and nanotube networks

Electronic conduction emerges when filler contacts or near-contacts form a connected path. Near the formulation-specific percolation threshold, small changes in loading, dispersion, aggregate structure or orientation can produce large changes in measured resistance. A molding parameter has no universal directional effect: published carbon-black injection-molding studies report changes with pressure, packing and depth that depend on the local skin/core structure.

Ask the compounder for filler grade, target loading, dispersion controls, masterbatch let-down practice and resin compatibility. Verify actual finished-part location and measurement direction; a conductive core does not guarantee a conductive exposed surface. Regrind, colorants and other additives should be controlled as formulation changes until qualified.

Migratory antistats versus non-migrating dissipative polymers

A migratory additive can reach the surface and attract moisture, creating a humidity-sensitive pathway. Cleaning, handling, aging and packaging may alter the surface condition. A non-migrating polymeric antistat instead relies on a continuous or interpenetrating ion-conductive phase; supplier guidance emphasizes compatible compounding and application-specific loading. Do not infer that every “permanent” grade is equivalent or humidity-independent without its data and a finished-part test.

Base resin and moisture

Resin choice changes filler dispersion, crystallization, flow and additive migration. Moisture can also change an insulating polymer’s measured resistance; ASTM D257 notes environmental and electrification effects. For nylon parts, record both pellet drying history and specimen conditioning, since these answer different questions: processing stability and in-service electrical behavior.

Working hypothesis: if a molded surface reads high while an exposed core reads low, investigate skin/core distribution before increasing filler. Any destructive sectioning test is diagnostic only; it does not replace the specified measurement on the intact part.

2 How molding can break an otherwise sound electrical path

Variable to control	Plausible electrical effect	Evidence to collect
Melt and mold temperature	Change viscosity, solidification and filler rearrangement; direction depends on compound and geometry.	Actual melt/mold temperatures, lot and location-matched resistance.
Injection speed / shear	Change filler orientation, migration and skin thickness.	Fill profile, gate-to-end-of-fill map, surface/core comparison.
Packing pressure / time	Change local density and conductive contacts; published effects are conditional.	Part weight, cavity pressure if available, controlled setting comparison.
Gate, wall, weld line	Produce direction-dependent pathways and locally disrupted networks.	Mark flow direction, gate, weld line, thickness and probe location.
Drying, residence, regrind	May alter formulation state, degradation risk or additive concentration.	Drying log, residence history, regrind percentage, resin/compound lot.

Do not change several settings at once. Lock material lot and test conditions; then run a small controlled process study inside the resin supplier’s safe processing window. Read surface and volume response separately, with mechanical and dimensional checks. The carbon-black literature demonstrates that injection and packing pressure can change depth-dependent resistivity; it does not justify a universal “more pressure means lower resistance” rule.

Geometry matters

A plaque molded from the same pellets may have a different thickness, flow length, cooling profile and surface layer from the production component. Qualification should include representative sites such as near-gate, end-of-fill and weld-line regions, but electrode placement on a rib, curve or textured face must be validated before those data become acceptance data.

3 Measure the right property under the right standard

Resistance (ohms) is the observed electrical response of a particular electrode/specimen arrangement. Surface resistivity (often reported as ohms per square) and volume resistivity (ohm-m or ohm-cm) are geometry-normalized quantities calculated under a defined method. Never compare an unconverted point-to-point reading with a datasheet resistivity limit.

Method	Appropriate role / boundary
IEC 62631-3-1:2023	DC volume resistance and volume resistivity of solid electrical insulating materials.
IEC 62631-3-2:2023	DC surface resistance and surface resistivity of solid electrical insulating materials. Electrode arrangement matters.
ASTM D257-14(2021)e1	DC insulation, surface and volume resistance with calculated resistivity; its scope excludes moderately conductive materials. Report voltage and electrification time.
ASTM D4496-21e1	DC resistance/resistivity for moderately conductive materials within its stated range; useful when D257 is outside scope.
ANSI/ESD STM11.11-2022 / STM11.12-2021	Surface / volume resistance methods for planar materials, including preparation and conditioning. Verify applicability to part geometry.

IEC 60093 is withdrawn/replaced; do not cite it as the current IEC method. Test-method choice is a technical decision based on range and specimen form, not a menu of interchangeable numbers.

Minimum report fields

Record standard and edition; property and units; meter/fixture and calibration; electrode geometry/contact; voltage and electrification time; temperature and relative humidity; conditioning duration; cleaning/handling; measurement direction and exact part location; thickness where relevant; cavity, shot, lot and production time; all readings, instrument limits and acceptance rule. A value outside the meter range should be reported as a limit, never as an exact number.

4 Troubleshoot by pattern, not by a single failed number

Observed pattern	Most useful next check	Likely branch
All sites high, plaques high	Check compound identity, filler/additive loading, dilution and method range.	Formulation or test setup.
Surface high, core/volume lower	Map intact surface; examine cross-section only as a diagnostic.	Resistive skin or surface depletion.
One cavity or weld line high	Overlay flow/cooling map and verify electrode contact.	Local molding/geometry effect.
Dry test high, humid test low	Repeat after controlled conditioning; check antistat chemistry.	Moisture-dependent surface pathway.
Readings shift after wiping / aging	Standardize handling, cleaning and elapsed time.	Surface film, contamination or migration.
Instrument/lab disagreement	Exchange identical conditioned specimens; compare voltage, dwell and fixture.	Measurement-system difference.

Start by remeasuring a retained specimen under the agreed method. If the result repeats, compare multiple locations on the same part, then multiple parts from the same shot/cavity, then independent lots. This nested sequence distinguishes location effects from short-term process variation and batch variation.

Corrective action hierarchy

First correct a method mismatch or uncontrolled conditioning. Next address a localized gate, flow or cooling problem with a controlled process trial. Change the formulation only after the electrical mechanism and part-level evidence support it; increasing carbon filler may affect flow, appearance and mechanical performance. Requalify electrical, mechanical and dimensional properties after a material change.

5 A defensible sampling and verification plan

Qualification: agree on the target property/range and the actual service environment. Test representative production parts from each cavity and from start, steady-state and end of a run. Include critical locations, flow direction and thickness. Repeat at the specified standard conditioning and at justified low-humidity or other service conditions. Predefine retest, outlier and instrument-limit rules before seeing results.

Routine control: retain material-lot, drying and molding records; use a fixed fixture and mapped measurement locations; trend individual readings rather than only a mean. Set sample size and frequency from product risk and observed within-cavity/between-cavity variation. No numeric sampling plan is asserted here because neither process capability nor customer acceptance criteria have been supplied.

Release decision: use the specified intact-part test. A passing resin plaque or average does not override a failing critical part location. If the intended protection depends on low charging, grounding or shielding, resistance testing alone may be insufficient; verify the additional performance requirements relevant to the application. ESDA identifies triboelectric charging, discharge and field control as separate packaging concerns.

Typical applications and what to verify

Application	Part-level question
ESD handling trays / fixtures	Is the contact surface consistently in the specified resistance range and appropriately grounded in use?
Electronic housings / sensor supports	Are exposed surfaces and contact points stable after conditioning, cleaning and aging?
Industrial dust-control covers	Does the chosen material reduce charge accumulation in the actual service humidity?
Conductive nylon components	Does the required current path survive molding orientation, weld lines and assembly?

Practical release criterion: the approved specification should name a method and edition, a part location, a conditioning state, a numerical acceptance range supplied by the customer, and a sampling/retest rule. Without those, “antistatic” is not a verifiable finished-part requirement.

Method note: the standard editions named above identify the scope of each test. Use the full applicable standard for laboratory procedure and customer acceptance. Process effects depend on compound and geometry; no experimental data or product-specific performance claim is presented as TechInherit data.

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