Assessing Passive Static Dissipators

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***Abstract*— Passive static dissipators such as needle bars, static brushes, tinsel strands, ionizing cords and ionizing rods provide cost effective static control for many industrial applications. An assessment matrix includes eight criteria including electrical performance and mechanical durability to consider when selecting an appropriate dissipator. A method for assessing the electrical performance of passive dissipators is to mount the dissipator above a metal plate. The output current of the dissipator is measured as a function of plate voltage. These I-V measurements show that the output current of passive dissipators is zero below a threshold voltage. Analysis shows that the dissipator current increases with the square of the plate voltage above the threshold voltage. Better passive dissipators have lower threshold voltages and have higher output currents above the threshold achieved by having a larger number of sharper tips or needle points.**

I. Introduction

Controlling static in web conveyance operations has been a challenge at least since 1904 when a wire electrified with alternating, high voltage was claimed to remove static from paper or yarn [1]. Static dissipators are broadly divided into two categories, active and passive [2]. Active static dissipators have power supplies to energize sharp pins or wires that generate corona ions. Many active static dissipators or "static bars" are commercially available. The installation for a typical application can cost several thousand dollars for the static bar, cables, power supply and controller.

Passive static dissipators such as static brushes, needle bars, tinsel, ionizing cords, and ionizing rods are cost effective alternatives. Passive static dissipators have no power supplied. To operate, passive dissipators need only to be connected securely to electrical ground. They generate corona ions by intensifying the electric fields induced by static on the charged "targets." The installation costs of passive dissipators for typical applications cost only a few hundred dollars for the dissipator, mounting hardware and ground connection.

When choosing a static dissipator, cost and performance are the first considerations. Also consider durability, sensitivity to contamination, installation geometry, operator convenience, maintenance, and service life when selecting a dissipator.

II. Dissipator Selection Matrix

Table 1: Summarize selection criteria

	Selection Criteria	Tinsel (baseline)	Ionizing Cord	Static Curtain	Active Static Bar
1	Cost	0	0	–	– –
2	Dissipation performance	0	0	0	+ +
3	Mechanical durability	–	+	– –	+ +
4	Potential for contamination	– –	–	– –	+ +
5	Installation geometry (space)	0	+	– –	– –
6	Operational convenience / interference	0	0	– –	+
7	Maintenance	0	0	– –	0
8	Service life	0	+	– –	+ +

When selecting a dissipator, I recommend assessing the selection criteria with a small group of the people who will be impacted by the decision; a lead operator, a maintenance worker would will install the dissipator, the machine engineer responsible for maintaining the area, and the product engineer.

List the selection criteria and add additional criteria identified by your team missing from Table 1. Chose a "bench mark" dissipator that is familiar to everyone such as tinsel. By definition, the benchmark should be "neutral" or "0" for most criteria. Mechanical durability and contaminate generation are a known concerns for tinsel that I have indicated in Table 1.

List the candidate dissipators across the top such as an ionizing cord, a static curtain, and an active static bar. Static curtains are fabrics made of static dissipating fibers. Static curtains or static blankets have been used for many years usually on unwinding rolls, winding rolls, or as covers for idler rollers. Several new static curtains are now commercially available.

Together with the small group of stake-holders, move down the list of selection criteria and assess the relative merits and disadvantages of each candidate and assign one of five rating in Table 2 to each selection criteria for each candidate.

Table 2: Assessment Ratings

Rating	Comment
– –	strong disadvantage
–	disadvantage
0	neutral
+	advantage
+ +	strong advantage

The goal here is to arrive at a consensus decision. My experience is that making a unanimous assessment of any one criteria is unnecessary and unproductive. Rather, in the end, the selection matrix documents the consensus opinions of the team and helps clarify the decision.

A. Cost

Assessing cost is easy. Ionizing cords and tinsel have similar costs. The purchase price of an active static bars is much higher, so I assigned "– –" in Table 1 indicating a clear disadvantage.

B. Dissipation Performance

When a new or unfamiliar static dissipator is a candidate, measure the I-V performance of the new dissipator and a benchmark dissipator for comparison prior to the selection meeting.

1) Experimental Apparatus

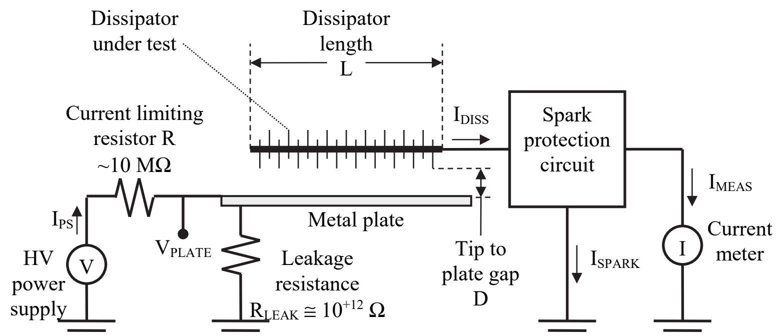

Fig. 3: The electrified metal plate simulates a charged target. The current from the dissipator is measured by the current meter that is protected by the spark protection circuit.

The performance of an ionizing cord was measured by applying voltage V to the metal plate in Figure 3. The measured currents I_{MEAS} flowing from the dissipator to ground are tabulated in Table 4.

Table 4: Applied Voltage and Measured Current

V_{HV} (V)	I_{MEAS} (μA)	V_{PLATE} (KV)		V_{HV} (V)	I_{MEAS} (μA)	V_{PLATE} (KV)
0	0.0	0.00		0	0.0	0.00
1000	0.0	1.00		-1000	0.0	-1.00
1497	0.1	1.50		-1495	0.0	-1.50
2020	2.5	2.02		-1997	-0.2	-2.00
2654	11.1	2.65		-2557	-1.4	-2.56
3240	24.8	3.24		-3034	-4.2	-3.03
3958	46.7	3.96		-3587	-9.6	-3.59
4769	78.2	4.77		-4161	-17.6	-4.16
5674	118.8	5.67		-4769	-28.3	-4.77
6903	181.9	6.90		-5546	-46.2	-5.55

The metal plate simulated a charged target near the dissipator. The leakage current from the metal plate to ground should exceed $10^{+12}\ \Omega$ so that most of the output current of the power supply flows through the dissipator under test to ground. The tip to plate gap D could be varied over a range of 0 to 2 inches.

The current meter was protected by a spark protection circuit [3] designed to be a low pass filter that shunts high frequency spark energy to ground. A resistor R between the high voltage power supply and the metal plate limits the current available to the metal plate protecting operator who may inadvertently touch the plate and limiting the energy available to sparks between the metal plate and the dissipator under test. Energetic sparks from the electrified plate to the dissipator under test can damage the dissipator.

Current I_{MEAS} was recorded as the voltage V applied to the metal plate is varied over a range of 0 to ±10 KV. Table 4 shows measurements for a commercially available ionizing cord having a length of 1 foot with a 0.5 inch tip to plate spacing D. The shaded plate voltage was calculated by knowing the applied voltage, the measured current, and the voltage decrease across the current limiting resistor; $V_{PLATE} = V_{HV} - I_{MEAS} \times R$.

2) Analysis

Corona ions having number density n, charge q and mobility b in (1) flow from the passive static dissipator to an area A on the electrified plate by the electric field E.

$$I_{DISS} = A_{PLATE}(nqb)E \tag{1}$$

The plate area A where current flows is determined by the design of the passive dissipator and the brackets mounting the dissipator above the metal plate. A first simplifying assumption is that area A is a rectangle having a length L of the dissipator under test and a width D equal to the tip-to-plate gap. This crude, simplifying assumption is sufficient for order-of-magnitude analysis.

The second simplifying assumption is that the number density of ions n in (2) is proportional to the electric field E above a threshold electric field E_{TH}.

$$n = \alpha(E - E_{TH}) \tag{2}$$

The proportionality constant α in (2) determines how many ions are produced. For example, α would be higher for a dissipator with a large number of finer, sharper points.

A third simplifying assumption is that the electric field E near the plate surface in (3) is the plate voltage V_{PLATE} divided by the tip-to-plate gap D.

$$E_{PLATE} = \frac{V_{PLATE}}{D} \tag{3}$$

The nominal electric fields near the surface of the dissipator will be much higher than the electric fields near the plate. However, the magnitude of the electric fields outside the corona discharges near the dissipator are proportional to the E_{PLATE}. The variation in the electric fields with the plate voltage V_{PLATE} is captured by (3).

With these three simplifying assumptions, the dissipator current in (1) is (4).

$$I_{DISS} = KV_{PLATE}(V_{PLATE} - V_{TH})\left(\frac{L}{D}\right) \quad ; \quad K = \alpha(qb) \tag{4}$$

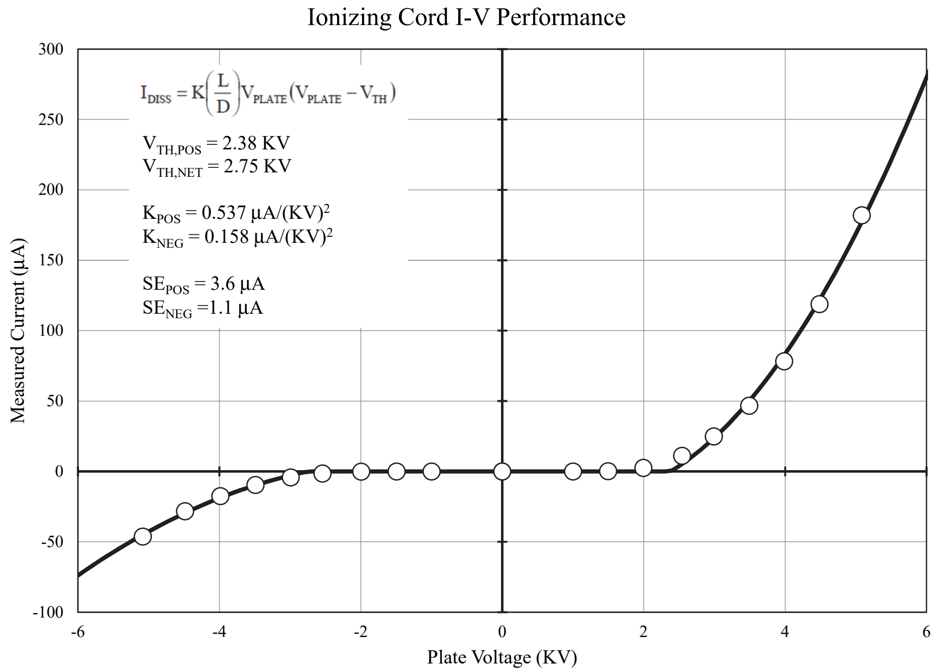

Fig. 5: The measured I-V data in Table 1 is fit with the empirical model in a least squares sense by adjusting the threshold voltage V_{TH} and constant K.

The measured dissipator current as a function of the plate voltage for the ionizing cord in Table 4 were fit in a least squares sense in Figure 5 by adjusting the threshold voltage V_{TH} and the constant K in (4).

Our semi-empirical model (4) fits the ionizing cord measurements having standard errors less than 5 µA. The dissipator current for positive polarity is much higher than the currents measured for negative polarity. So, the data was fit using different coefficients for positive and negative plate voltages.

For positive plate voltages, negative ions flow from the dissipator under test to the plate. The threshold voltage $V_{TH\text{-}POS}$ is lower (better) than $V_{TH\text{-}NEG}$. Additional work is needed to understand why negative corona has a lower threshold voltage than positive corona at the ionizing tips of the ionizing cord.

K_{NEG} is higher (better) than K_{POS} by ~3X. From (4), K_{POS} and K_{NEG} include the mobilities of ions moving from the dissipator towards the plate. The difference between K_{POS} and K_{NEG} may be due simply to the difference in ion mobilities. We expect K_{POS} to be larger than K_{NEG} because the mobility of negative ions in air (~ 2.2×10^{-4} m^2/V-s) are higher than for positive ions (~ 1.6×10^{-4} m^2/V-s) [4].

The lower $V_{TH\text{-}POS}$ and large K_{POS} indicates that the passive dissipator produced more current when the voltage applied to the metal plate was positive. The passive dissipator will perform better when target carries positive charge. This is apparently a characteristic of all passive dissipators that distinguish them from active ionizers that produce nearly equal currents for positive and negative applied voltages [5].

C. Mechanical Durability

Mechanical durability is important in industrial applications. The factory floor environment requires durable designs and installations. The bristles on tinsel are prone to being compressed when the tinsel is handled during installation and during machine cleaning and job set-up operations. Once compressed, the bristles generate fewer ions and the electrical performance of tinsel suffers. Ionizing cord are much more durable.

Static curtains are typically installed to touch unwinding rolls, winding rolls, or moving webs. Touching causes wear concerns raising mechanical durability issues.

Active static bars are usually located 2” to 6” from moving targets so contact is a non-issue. Some commercially available static bars have rugged fiberglass exteriors with epoxy cast parts making them very durable in manufacturing environments.

D. Potential for Contamination

Consider two separate contamination issues. The first issue is that some dissipators generate contaminants. Tinsel strands break over time and may contaminate the product. If this is important, then tinsel has a known problem warranting a “– –” rating in Table 1. While an ionizing cord is much less likely to generate contaminants, it may wear by intermittent contact with the target and shed fibers warranting a “–” rating in Table 1. Active static bars have clearly superior performance, so I assign a “+ +” rating in Table 1.

The second issue is that some product (filter media, food packaging, medical devices) are sensitive to airborne contaminants. To minimize the deposition of airborne contaminants, static charges on the target must be maintained as close to zero as possible. Active static bars are required for products sensitive to airborne contaminants because passive dissipators always leave a threshold level of charge on the target.

E. Installation Geometry

The installation geometry determines, in part, the neutralization efficiency of the dissipator. Static dissipators should be installed so that the charged target is closer to the dissipator than all other grounded metal objects. For web conveyance applications, static dissipators should be installed on free web spans approximately midway between idler rollers. However, some production machines are congested leaving little room for the installation of a dissipator. With tinsel as a benchmark, ionizing cords are smaller and require less room (positive rating). Active static bars are typically larger and require more room (negative rating).

F. Operational Convenience / Interference

Listen carefully to comments by operators and maintenance personnel about how installing a static dissipator may impact operations such as threading a machine, changing products, and cleaning. Passive dissipator performance increases when they are installed closer to the charged target. This usually means that they have higher impact on operations. They are simply more often in the way making them more prone to damage and removal.

G. Maintenance

Dissipator maintenance depends on the cleanliness of the operation. Active static bars installed in clean room require very little maintenance. Ionizing cords installed near solvent coater may need to be replace often. Again, listen carefully to the comments from maintenance personnel and machine engineers.

H. Service Life

My experience is that passive static dissipators have a service life in the range 3 – 12 months. This depends on the installation. For example, intermittent contact with the target shortens life. The active service life of active static bars is in the range 5 – 15 years.

III. Conclusions

When selecting a static dissipator for a specific application, cost and performance are important criteria. I suggest assessing the selection criteria with a small group of people who would be impacted by the decision. A selection matrix may be used to guide the discussion. The dissipator current measured as a function of plate voltage quantifies performance. Dissipators with higher currents perform better. Also consider the sensitivity of the application to contamination. Passive dissipators can generate contaminants. And, passive dissipators leave a threshold amount of static on the charged target that attracts airborne contaminants. For some, sensitive applications, active static bars must be used and passive dissipator should be prohibited. Operational issues such as interference with operator task, maintenance, and service life should be included in the selection.

References

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[5] K. Robinson, "Static Dissipator Neutralization Efficiency," Static Beat | pffc-online.com, Jan. 3, 2014.