ANTI-STATIC CASTERS:

The Newest Development in the Ongoing Battle Against ElectroStatic Discharge

by The Darnell Corporation

DARNELL CORPORATION

INTRODUCTION

Electrostatic discharge (ESD) is the spark you see and feel when you touch a doorknob after walking across a carpet on a dry day. You may think it is nothing more than a "little zap," but ESD has to reach 3,000 volts before it is even perceptible by humans. A computer chip, on the other hand, can be seriously damaged or destroyed by as little as ten volts of ESD. The increasingly critical workplace requirements of the electronics industry have prompted research for solutions to the hazards of ESD. The presence of ESD in the environments where the manufacture, construction and assembly of microprocessors, circuit boards, computers and sensitive electronic equipment takes place is a significant problem. Damage caused by ESD is a very costly and frustrating challenge encountered by these industries. Other environments requiring the minimization of ESD include clean rooms, surgical suites and other medical environments, and areas where combustible gases are present.

How does a typical ESD event occur? Picture an assembler working on a circuit board for a computer. This individual sits at a workbench on a chair with casters, and additional equipment or parts will sit next to them on a cart, also with casters. As those casters repeatedly move across the floor, they generate an electrical charge. If the caster wheels are not designed to conduct the charge into the floor, then the charge will transfer from the casters into the cart and remain there in the form of static electricity. When the worker comes in contact with the cart, that charge, in the form of ESD, will harmlessly travel into the worker's body (human beings are excellent conductors of electricity). The next time the worker touches an ESD-sensitive component, such as a computer chip, the resulting ESD discharge can damage the chip.

There is no single method of dealing with ESD, but a series of safeguard strategies should be incorporated into the workplace environment where ESD is a factor. These strategies usually include charge prevention, grounding, shielding, neutralization and education.

Conductive or dissipative casters are an important, but often overlooked, part of an overall system of protection against ESD. The Darnell Corporation in City of Industry CA, has manufactured casters and wheels for a wide variety of uses since the firm was founded 75 years ago. Through exhaustive research, Darnell has developed a line of conductive and dissipative casters that should be part of any integrated ESD protection program.

these unbalanced charges are unstable. If these unstable charges cannot move because there is no path, this charge state is referred to as static electricity because it tends to remain at rest, or static, until it comes in contact to a body with a different positive or negative electrical potential.

ELECTROSTATIC DISCHARGE DEFINED

Since static electricity on a material is created from an imbalance of electrons, it is not in a natural or stable state and will, when possible, return to a natural state. When this is done rapidly a zap or spark associated with rapid electrostatic discharge occurs. An electrostatic discharge is a transient electrical discharge, a transfer of electrons, occurring between two objects that are charged to different electrostatic potentials. Therefore, the spark you feel when you touch something after walking across a carpet on a dry day is not static electricity, it is electrostatic discharge. It is the transfer of electricity. When an electrostatic discharge event occurs, the charge which was formerly at rest begins to move, generating heat. Since these discharges occur in nanoseconds, the rate of heat buildup is explosive. Generally this process takes place so quickly that we cannot detect this heat, but microscopic examination of electronic components subjected to ESD have revealed melted silicon chips.

Remember, we can feel these "zaps" if the discharge is over 3,000 volts, but electrostatic discharges below the threshold of sensation are frequent and very lethal to electronics and associated semiconductor devices. Ten volts, well below the levels a human being can detect, can destroy a sensitive electronic component. Simply walking across the floor may generate charges up to 30,000 volts.

ESD SAFEGUARDS

A system of ESD protection is based on the physical law that, all things being equal, electricity always takes the path of least resistance. Providing a low resistance path in order to harmlessly drain ESD charges should include conductive or dissipative casters as well as grounding wrist straps, grounding chains and conductive flooring. These solutions offer a pathway for the static electricity to flow, and thus seek to equalize itself. In the absence of these safeguards, the static electricity will seek the next best way to equalize itself, which is how a damaging ESD event can occur.

The principle ESD safeguard for stationery machinery is proper grounding, which goes a considerable way in eliminating ESD problems. Items which are mobile, however, such as human beings and carts and other movable equipment, offer a potential for damage from an ESD event. How well do the various ESD safeguard options work? Grounding straps are effective, but they are susceptible to human error. Employees can step away from the work station, or unknowingly pull the strap out of its grounding connection. Grounding chains are also effective, but they can lose this effectiveness in the event contact is lost with conductive parts of the flooring material.

Conductive or dissipative casters on all wheels of both chairs and carts offer excellent protection against ESD because they are always in contact with the conductive flooring.

ESD PROTECTION

TYPE OF MATERIAL	SURFACE RESISTANCE	ESD PROTECTION
Conductive	$< 10^5$ Ohms	Excellent
Static Dissipative	$> 10^5$ Ohms $< 10^{12}$ Ohms	Good
Insulative	$> 10^{12}$ Ohms	None

TABLE 1.1

STATIC ELECTRICITY DAMAGE IN INDUSTRY

During the processing of film materials or plastics, static electricity can cause materials to cling to each other, causing production slowdown or quality problems. In clean rooms, electrostatically charged materials can hold static-laden dust, preventing these dust particles from being circulated and picked up by the air filtration system of the clean room. Clean rooms are classified by the allowable number of various sized particles contained in one cubic foot of air. For example, a Class 1,000 clean room has no more than 1,000 particles measuring 0.5 microns in size and no more than seven particles measuring 5.0 microns in size. Today, with the semiconductor industry producing electronic pathways of less than one micron, many clean rooms are built and maintained at a Class 1 standard, which limits particles to those only as small as 0.1 microns. To put these numbers in perspective, a human hair is about 75 microns in diameter. Untimely release of dust particles can critically damage susceptible components.

Semiconductor chips, which are created through a complex, costly and time-consuming process, are extremely susceptible to ESD damage. Because of the complex manufacturing process, it can take three months or more for a silicon wafer to go through the manufacturing stages to become a computer chip. Each of these processes is fraught with hazards. With every process a chip goes through, its value increases. Chips valued at up to several hundred dollars apiece can easily be rendered useless by an ESD event. ESD damage to electronic components is not readily apparent because it is not generally visible as it occurs and may be latent or not show up in functional testing of electronic devices. ESD damage may lead to premature or intermittent failure. The cost of ESD damage is not simply the cost of the components, but also includes the cost of labor and may include all of the expenses associated with field repair. Other costs include lost business due to customer dissatisfaction. Many companies have implemented ESD control programs that have reduced their quality defects, resulting in significant cost savings. ISO 9000 certification is also driving the need for proper ESD control programs. (*Source: IRI Sentinel, 3rd QTR. 1996*)

STATIC ELECTRICITY

To fully understand the causes of damaging electrostatic discharge, a discussion of static electricity must be reviewed. Static electricity accumulates on the surface of any non-grounded conductor – almost all plastics and textiles, many metals, as well as the human body. On a microscopic level, static events are an everyday occurrence. Clinging clothes, dust build-up on television and computer monitor screens, the unexpected static shock as we touch an object such as a door knob, pet, or other object, or the clinging plastic wrap that does not want to be thrown away. On a larger scale, lightning is a very violent electrostatic discharge event.

The extent of the contact, the materials involved, relative humidity, and the texture of the materials will all influence the amount of the charge generated.

An electrostatically charged object is surrounded by an electrostatic field. To experience an electrostatic field, wave the back of your hand across a television or computer screen. The sensation you feel is the hairs on the back of your hand being pulled by the electrostatic field. This is called charge induction. Charge induction lets an electrostatically charged object charge other nearby objects without actually touching them; sometimes from as far away as several feet.

How does this electricity generate? When contact and separation, such as sliding, rolling or rubbing, occurs between materials (such as a caster rolling across a floor), a transfer of electrons on the surface of the materials results. This process is referred to as triboelectric generation. The result is an imbalance of electrons called an electrostatic surface charge and this charge can be either a positive or a negative one (an abundance of free electrons results in a negative charge, a deficiency of free electrons results in a positive charge). Because electrical charges always seek to equalize,

CONDUCTIVE - DISSIPATIVE - INSULATIVE MATERIALS DEFINED

Only materials that offer protection against the generation of static charges from triboelectric generation can be considered antistatic. In general, materials may be classified into three categories based on their resistance to electrical flow and their degree of ESD protection:

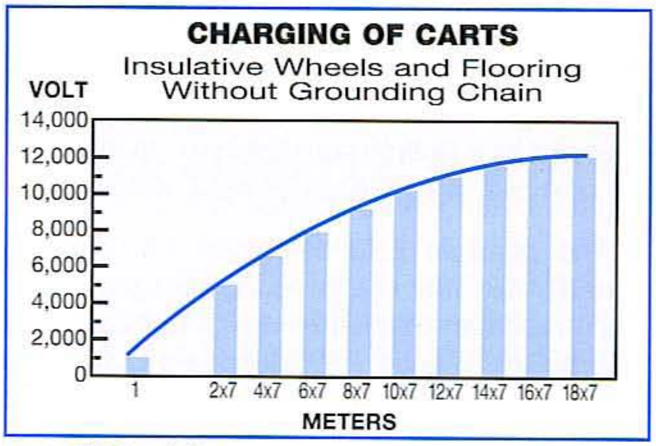
- **CONDUCTIVE.** A conductive material conducts, or passes static electricity and has a low resistance to electrical flow. Military standards define conductive as materials with surface resistivity of less than 10^5 ohms. Conductive materials offer the best safeguards for ESD protection.
- **STATIC DISSIPATIVE.** A static dissipative material has medium resistance to electrical flow and will conduct electricity, but not at as fast a rate as conductive material. Military standards classify dissipative materials as having a surface resistivity of equal to or greater than 10^5 ohms but less than 10^{12} ohms. Dissipative materials offer good safeguards for ESD protection.
- **INSULATIVE.** Insulative materials have a high resistance to electrical flow and are not a good conductor of electricity. Military standards define insulative as having surface resistivity of greater than 10^{12} ohms. Insulative materials offer no ESD protection.

Therefore, only conductive or static dissipative materials should be used in casters found in ESD-safe areas because they allow static electricity to flow through the wheels and into the conductive flooring *(see table 1.1)*. Insulative materials should not be used since they commonly generate and hold a static charge, and allow the charge to drain away only over a protracted period of time. The danger is that the static electricity will discharge into an ESD-sensitive component before it can neutralize any other way.

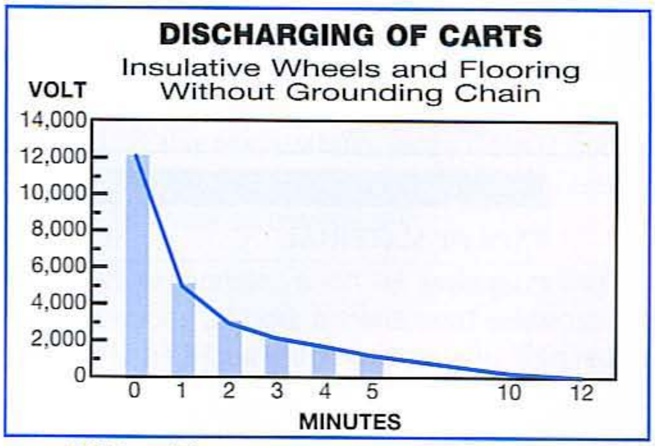
RESEARCH AND TESTING

Tests were conducted in Sweden by Erling Krog-Jensen of Ericsson Telecom AB, and Lennart Hjarn of ESD Management AB, to investigate the effectiveness of carts equipped with grounding chains and insulative wheels (high resistivity, low conductivity). The tests were conducted on ordinary factory carts with two conductive loading levels and a steel frame. The cart was moved at normal walking speed and then the potential was measured. A test was performed with insulative wheels and insulative flooring without a grounding chain. *(See chart 1.1 and 1.2)*. The cart charged to between +800 and +12,000 volts, depending on the distance it was moved. When the cart was stopped it followed a normal discharge curve down to zero volts. They suggested the following explanation to the test results on insulative flooring:

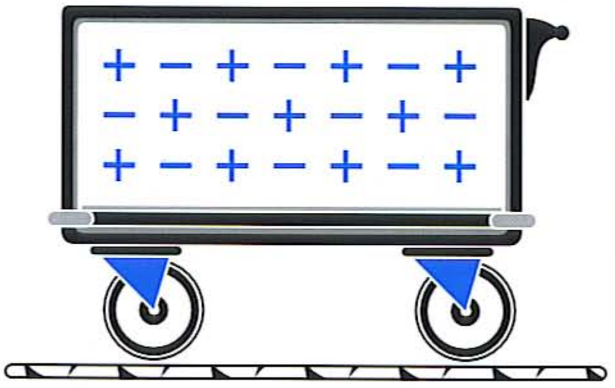
"If a cart with insulative wheels is moved the wheels will be charged. This charge will cause the cart frame to be charged in three ways.



source: ESD Association — CHART 1.1

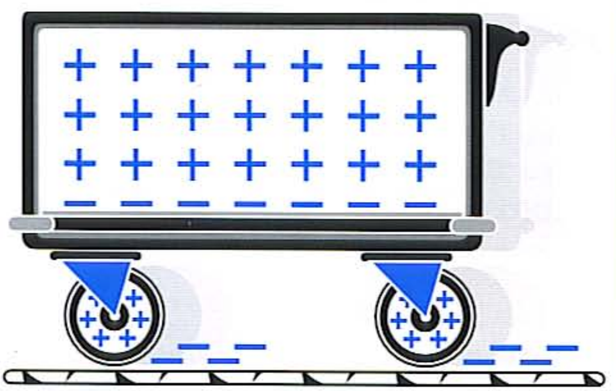


source: ESD Association — CHART 1.2



An uncharged cart has the same amount of positive and negative charges.

source: ***ESD Association*** **FIGURE 1.1**



The wheels of a cart which is moved on a floor will be charged. The charged wheels will induce a charge to the cart.

source: ***ESD Association*** **FIGURE 1.2**

1. Corona charging will give the frame the same polarity as the wheels.

2. Induction will bind charges of the opposite polarity of the wheels to the frame surface close to the wheels, thereby giving the rest of the frame the same charge polarity as the wheels. *(see fig. 1.1 and 1.2)*

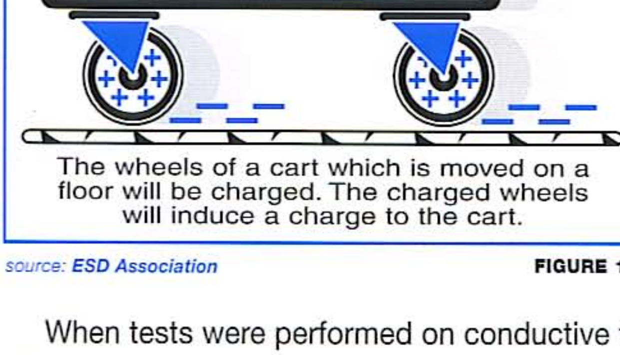
3. Conduction through the wheel material will charge the frame to the same polarity as the wheels."

The study further stated, "All three ways will thus give the same polarity to the frame of the cart. The corona charging and the inducted charging occur immediately when the cart is moved, while the charging through conduction will take a time which depends on the resistance from the wheel surface to the frame."

The pair of researchers also found that, "A cart with conductive wheels does also charge when moved on an insulative floor, but only to a certain degree. At a certain potential an equilibrium seems to be established between the conductive wheels and the floor material, prohibiting further charging.

When tests were performed on conductive flooring the researchers found unexpected charging of the cart when it was standing still, even when a grounding chain was used.

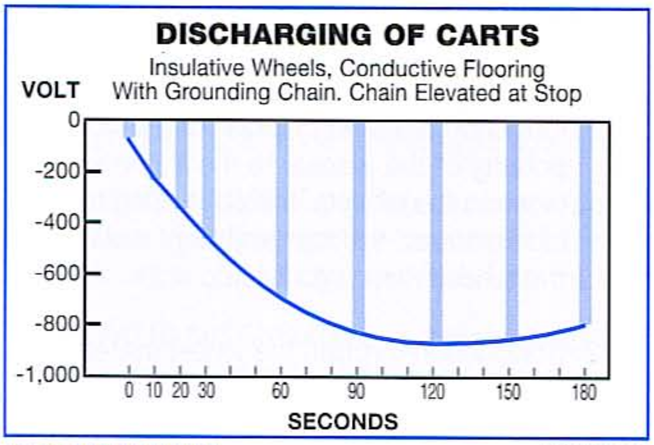
The voltage of the cart during movement never exceeded +50 volts, but when standing still on the conductive floor after movement the cart's potential changed polarity and began to show a negative value which gradually rose to several hundred volts. *(See Chart 2.3)*.



source: ***ESD Association*** **CHART 2.3**

The discharge of the cart with conductive wheels goes faster than that of the cart with insulative wheels, because the resistance to ground is lower."

"If a cart with a grounding chain is moved on a conductive floor it will not be possible to detect any charging of the cart in motion. The chain will make at least intermittent contact to the conductive parts of the floor and thus prohibit a build-up on the cart frame. Insulative wheels will, however, charge in the same way as without the chain. This means that



source: ESD Association

CHART 2.4

the positive charge on the wheels did attract and hold a corresponding negative charge on the wheel support surface. If the cart stops at a point where the chain does not make good contact to the ground, then the wheels start to discharge faster than the cart frame. The result is that the negative charges on the wheel supports, which have been held by the charge on the wheels, will be free and gradually charge the cart negatively. *(See chart 2.4)*.

In their conclusion, the researchers stated: "Insulative wheels can accumulate a charge when a cart is moved on an insulative or conductive floor, regardless of the cart being equipped with a grounding chain or not" if the cart stops at a point where the grounding chain does not make proper contact with the floor.

"The final conclusion is: ***For a good ESD protection the carts should be equipped with conductive wheels, preferably all [four] wheels, and the floor must be conductive with short distance between the conductive spots."*** (Emphasis added.)

THE SOLUTION

The Darnell Corporation offers two lines of "anti-static" casters suitable for use in areas where ESD sensitivity is a concern.

1) Conductive (CRX) Neoprene. For maximum ESD protection, Darnell offers a complete line of casters with Conductive Neoprene wheels. The previously mentioned research by Erling Krog-Jensen and Lennart Hjarn strongly supports the utilization of conductive wheels to insure good ESD protection of carts. Darnell's line of conductive wheel casters meet all the military specifications of conductive casters as defined in MIL-HDBK-263-B for the purpose of ESD protection, and are qualified and approved according to Underwriters Laboratories (UL) standards.

2) Static Dissipative (SDX) Polyurethane. A second line of casters with static dissipative polyurethane wheels offer practically the same level of ESD protection, but are made of carbon-free materials. Lab tests by Truesdail Laboratories, Inc., of Tustin, California, have confirmed that Darnell's SDX wheels conform to Military Handbook 263B, paragraph 3.17 requirements for dissipative material for the purpose of electrostatic discharge (ESD) protection.

Perhaps one of the most significant tests of Darnell's SDX wheels came from Micron Technology, Inc., a manufacturer of computer components. In a letter to Darnell, the ESD Control Department at Micron described the results of their test:

"Measurements were taken on a Micron cart (non-clean room) prior to installing the Darnell wheels. Without the drag chain, the cart measured 10^{14} ohms/ground with relation to the conductive floor. A 5,000 volt charge was induced on the cart. The 5,000 volt charge did not drain off the cart."

"The Darnell wheels were installed on the cart. . . The initial measurements were 10^{9} ohms/ground with relation to the conductive floor. With the Darnell wheels and the drag chain, the measurements were 10^6 ohms/ground with relation to the conductive floor. 5,000 volts were induced on the cart and the charge drained off in less than one second. ***In fact, the charge drained off so fast, an accurate measurement could not be taken."*** (Emphasis added.)

CONDUCTIVE vs STATIC DISSIPATIVE

Although carbon-based Conductive Neoprene (CRX) wheels offer the highest level of ESD protection, along with the benefits of a soft, quiet ride, they generally leave a carbon residue when rolling across a floor, often seen in the form of scuff marks. This carbon residue is generally unacceptable in clean rooms and some other environments. What is needed in these environments is a caster that still offers low levels of surface resistivity, but does not mark the floor with carbon residue or emit carbon particles into the air.

Darnell's static dissipative (SDX) wheels are non-marking and leave no residue or airborne particles. This is an important consideration in clean rooms or any industry where such contamination could have disastrous effects on computer chips, circuit boards, medical devices and other electronic instrumentation that requires ESD protection *(table 1.2)*.

CONDUCTIVE WHEELS vs DISSIPATIVE WHEELS

CLASSIFICATION	CONDUCTIVE (CRX)	STATIC DISSIPATIVE (SDX)
Material	Neoprene Rubber	Polyurethane
Surface resistivity	$< 10^5$ Ohms	$> 10^5$ Ohms $< 10^{12}$ Ohms
Volume resistivity	$< 10^4$ Ohms	$> 10^4$ Ohms $< 10^{11}$ Ohms
ESD protection	Best	Good
Shelf life	Moderate	High
Floor marks	Some marking	Non-marking
Shock absorption	Very good	Medium
Abrasion resistance	Good	Excellent
Max load capacity	up to 450 lb.	up to 1,500 lb.

TABLE 1.2

What gives SDX wheels their dissipative properties? The wheels are made from a blend of urethane and dissipative compounds. The precise formula was developed by Darnell and remains proprietary. The result is a caster and wheel with resistivity properties at practically the same level as carbon-based wheels, but without the problem of carbon residue and marking the floor. A thorough search of domestic caster manufacturers revealed no other casters available commercially that have the same properties as the SDX wheels from Darnell Corporation.

CONCLUSION

As stated earlier, there is no single sure-fire safeguard to protect against the hazards of electrostatic discharge. It takes a number of measures that, when used in unison, provide numerous options and pathways for static electricity to travel away from ESD-sensitive components and environments. Grounding straps can become disconnected. Grounding chains can lose contact with the floor or become entangled underneath a cart. Both of these instances are scenarios in which ESD protection is significantly compromised and the resulting damage to sensitive components is likely to occur.

Casters have been a largely overlooked area when considering ESD safeguards. Independent studies conclude, however, that conductive and dissipative casters manufactured by The Darnell

Corporation are particularly effective because they provide excellent contact with the conductive floor, providing a pathway for discharge. It should be emphasized that the most thorough studies recommend replacing all the casters on both carts and chairs.

The Darnell Corporation has designed casters that are classified conductive, meaning that they allow static electricity generated in a cart to flow harmlessly through the casters and into conductive flooring. Darnell's conductive (CRX) wheels (made from carbon-based materials) offer the highest level of protection against ESD and are suitable for use in virtually all applications where ESD is a concern. In clean room applications, ultra-clean conditions call for wheels that do not leave marks or emit particles into the air, or other forms of carbon-based residue, but still offer protection against ESD. Darnell's static dissipative SDX wheels meet this requirement. They are formulated from a proprietary blend of urethane anti-static compounds that offer protection against ESD that is still well within the levels of the highest protection available. The SDX wheels also provide higher load carrying capacity and offer greater abrasion resistance, qualities generally found on caster wheels made from high grade urethane materials.

THE DARNELL COMPANY

Since it's inception in 1921, The Darnell Corporation has striven to manufacture the world's finest casters and wheels. Over the years, Darnell casters have become recognized by both customers and competitors alike, as the premier line - the "Cadillac" of the industry. This time honored commitment to quality lives on at Darnell, right up to the present day which finds Darnell on the leading edge of movable mobile equipment caster technology.

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