A PRACTICAL GUIDE TO CONTROLLING ELECTROSTATIC CHARGES ON FILM WEBS

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ABSTRACT

Electrostatic charges develop on surfaces of film webs as they are transported through various converting processes such as rewinding, slitting, coating, laminating, bag making and sheeting. These charges often cause attraction of particulate to the web material and defects in printing and coating uniformity resulting in quality problems and customer dissatisfaction. Significant static charges can also cause operator shocks, interruption of process control electronics, fires in solvent coaters and reduction in machine speeds to overcome web transporting problems.

This paper will discuss the basic theory of static generation and the practical use of ionization equipment to control charges to a manageable level. This will result in reduced down time, safer operating conditions, higher productrvrty and enhanced product quality.

INTRODUCTION

Static electricity is the cause of many problems encountered in the transporting and converting of film webs in today's modem machinery. As progressing technology allows faster production speeds, static related problems are also increasing, hampering production and affecting product quality.

Static charges are generated on the surface of the film as it unwinds from the roll and as it contacts and separates from surfaces such as idler rolls, nip rolls and printing or coating rolls.

Charges exist in two polarities: positive and negative. Surfaces charged to the same polarity will repel each other. Opposite polarities will attract. A charged film of either polarity will attract to uncharged surfaces of insulators or conductors. These occurrences become especially evident in converting operations such as sheeting, bag making and die-cutting where the film is no longer under the control of the mechanical structure of the web and its transport system.

Film webs tend to develop high charges; 30 kV to 40 kV is common. The strong electrostatic fields associated with these charges attract dust particles, fibers, bugs and hair resulting in surface contamination. This causes obvious quality problems in printing, coating and laminating and cleanliness problems with food, medical and pharmaceutical packaging films. Uneven coatings and "wicking" of inks are often the result of static charges.

Electrostatic Discharge (ESD) of a charged conductor or a highly charged insulator can result in a sufficient enough energy release to ignite hazardous vapors in coating heads and gravure printing operations. An ESD event can also disrupt logic in PLC's and sensing equipment causing processing errors and costly down time. High charges, especially on a wind-up roll, can result in uncomfortable electrical shocks to the operator when approaching the roll or touching the machine frame.

By having a good basic understanding of static electricity and how it can be controlled in the film web processing, problems can be greatly reduced or eliminated resulting in more efficient web handling and improved product quality.

CHARGE GENERATION

Static electricity is an electrical charge on a surface. The charge is usually on an insulative material, such as the film web, and may be on a conductive surface if it is isolated from electrical ground. One example of an ungrounded conductor is a metal idler roll having worn bearings lubricated with nonconductive grease. When two surfaces are in contact, an exchange of electrons (negative charges) takes place between the two surfaces. When the surfaces are separated, the surface which has gained electrons becomes negatively charged. The surface giving up the electrons becomes positive. (See Figure 1.)

The materials involved and the pressure and speed of contact and separation affects the magnitude of the charge. This contact and separation process or frictioning is known as triboelectrification or tribocharging.

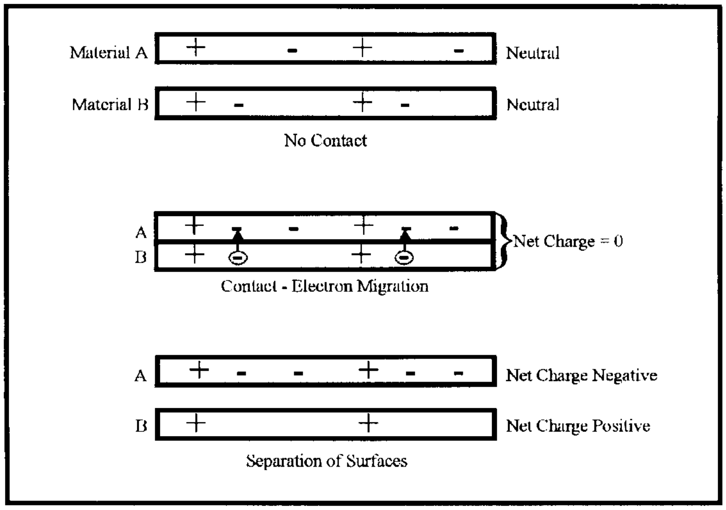

Figure 1
Triboelectrification

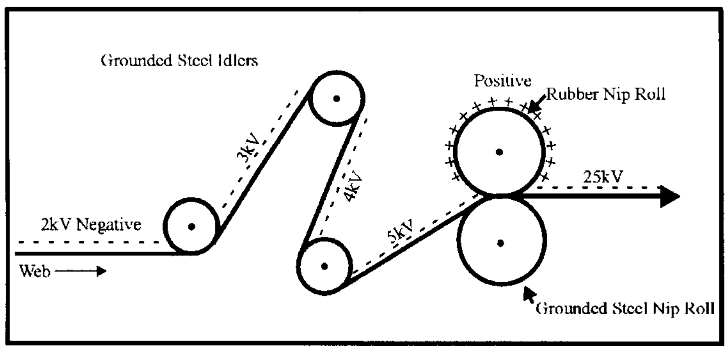

Figure 2
Cumulative Charges on Film Web Caused by Contact with Several Surfaces.

Since static charge build-up on a surface is a cumulative process, charge potentials can continue to increase each time the web contacts another surface as shown in Figure 2. This is evident in transport systems where the film may come in contact with several idlers.

If the web contacts an idler roll which is not turning freely or if it is pulled over a stationary bar or machine surface, higher charges can occur due to more intimate contact of the web against the surface resulting in more surface electron exchange. The amount of pressure of the web against another surface also results in higher charges for the same reason. Some typical areas within the web transport system that tend to generate significant charges on the web are:

1. Unwind
2. Nip rolls
3. Accumulator
4. Idler with insulative sleeve
5. Bow roll
6. Coating rolls
7. Corona treater
8. Lay-on roll

ELECTRICAL CHARACTERISTICS OF CONDUCTORS AND INSULATORS

Conductors

Electrically conductive components in the process machinery such as idler rolls, guides, brackets, core shafts and other various metal parts can charge by triboelectrification or induction charging if they are not properly grounded as shown in Figure 3. Since some of these components have high electrical capacitance, they are capable of storing significant levels of electrical energy. Their sudden discharge (arcing) to a human can result in a very uncomfortable or sometimes dangerous electrical shock. A charged idler roll may arc across the bearings to the shaft or machine frame. If this should occur in the area of solvent-rich vapors, fire or explosion could result.

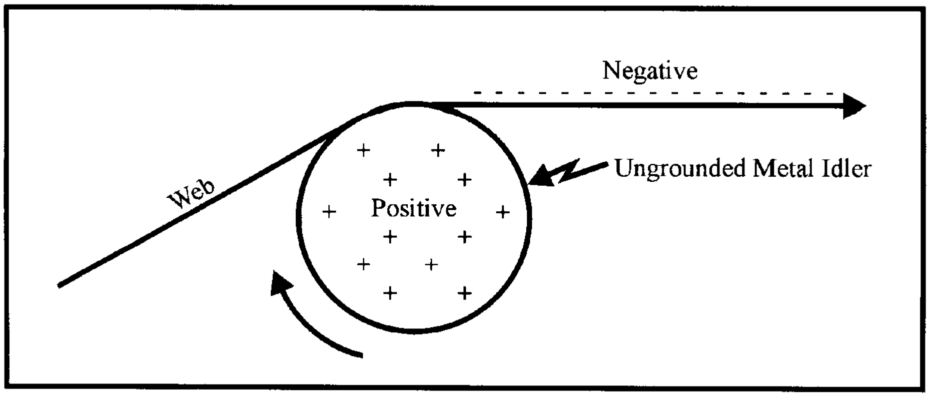

Figure 3
Tribocharging of Ungrounded Idler Roll and Film Web.

When charges develop on a conductor, the entire surface will be charged. The charge distribution will be of the same polarity and potential on all surfaces of the conductive body. If a conductor is properly grounded at all times it will not charge so hazardous discharges cannot occur. Grounding of machine components is typically accomplished thru mechanical contact to the grounded machine frame via clean metal-to-metal contact and good condition metal shaft bearings. Adequate grounding can be verified by using an ohmmeter and measuring from the clean unpainted surface of the component to the machine frame. Resistance should not exceed 1 megohm. When checking resistance-to-ground on idler rolls in hazardous areas, such as solvent coaters, this is extremely important. Measurements should be performed with the idlers running at their normal speeds. When the idler is stationary and resting on its bearings, sufficient ground may be indicated. When it is spinning the bearings sometimes tend to float in their races and lubricants and adequate ground may be lost.

Insulators

A film web is a good example of an insulator or dielectric and, unless it contains an antistatic additive or is subjected to excessive moisture, it will not conduct electricity. The film web will charge very readily through triboelectrification but cannot be discharged or neutralized through grounding as conductors can. Insulators can only be neutralized by adding opposite charges to their surfaces to balance or offset the electrical charge. This is accomplished through the use of air ionizers which will be discussed later in this writing.

Due to the nature of dielectrics, these materials do not allow for free electron movement within their structure. Therefore, a film web may exhibit areas of charges of both positive and negative polarities and varying levels of charge potentials across its surface.

DETECTING AND MEASURING ELECTROSTATIC FIELDS

Charge density is a function of field potential (volts) and the capacitance of the charged surface. It is expressed $Q = CV$ where: Q =charge in coulombs, C = capacitance, V = field potential in volts.

Since the capacitance is often difficult if not impossible to determine in a practical sense, electrostatic charges are usually evaluated and discussed in terms of field potential which can be easily detected and measured using electrostatic fieldmeters.

A fieldmeter is a non-contact, typically hand-held instrument, which is pointed at the target surface at some predetermined distance. The measuring distance is usually 1 or 2 inches. This distance is determined by the design of the individual instrument. The electric field induces a charge into the meter's sensing element. The charge is then displayed in terms of field potential on either a digital or analog meter reading in volts or kilovolts. The polarity of the charge is also displayed. In order to obtain accurate readings, the instrument's case must be grounded either through a wire connection or through the grounded operator holding the instrument. Some meters use a metal case and others may use a plastic material having additives which render the case electrically conductive to allow grounding.

Electrostatic fieldmeters utilize either an electrometer or a chopper-stabilized sensing element. Both achieve the same results; however, the electrometer type should not be used in proximity of an ionizer's emitter source or false measurements may occur as a result of ions collecting on its sensing probe. For the same reason it should not be used in the airflow of a forced air ionizer.

Field Suppression

When the charged film web passes over an idler roll or comes into contact or close proximity to another surface, its field becomes partially or totally collapsed (Figure 4). Even though the web is still charged, its field cannot be detected and measured. This condition is known as field suppression. The degree of suppression is dependent upon the distance relationship to the background surface, physical and electrical characteristics of the background surface, and the thickness of the charged material. Attempting field measurements in these conditions often results in errors when evaluating or auditing a process for static problems. In addition, in areas where field suppression is evident, static neutralizers cannot be effectively applied.

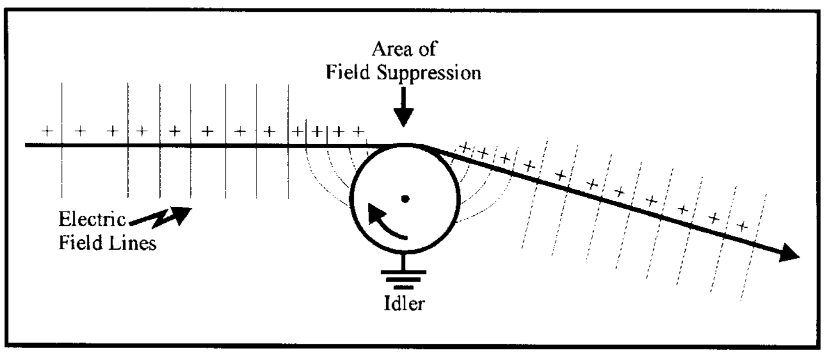

Figure 4
Example of Field Suppression Where Web Passes Over Metal Idler Roll.

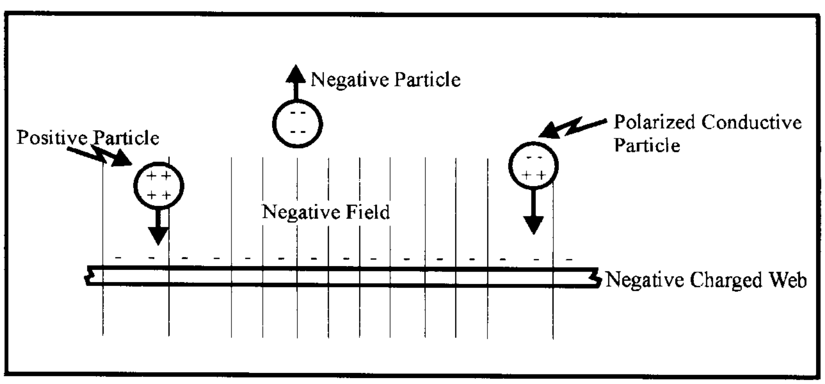

Figure 5
Field Effects on Airborne Particles.

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FIELD EFFECTS

Particle Attraction and Adhesion

The electric field from a charged film web is one of the primary sources of surface particulate contamination. Depending upon the magnitude of the charge, the field may extend out from the surface of the web a few inches or it may reach out several feet.

Airborne particulate, i.e. dust, dirt, lint and fibers, consist of both insulators and conductors and may be electrically neutral, or charged through triboelectrification. (See Figure 5) Particles charged opposite the polarity of the charged web and within the range of its field will be attracted to the surface of the web. Particles charged the same polarity of the web will most likely be repelled. Uncharged conductive particles influenced by the web's field can become polarized and may also be attracted to the web's surface. A charged web running a few inches off the floor can also attract debris from the floor.

When the web becomes contaminated due to the attraction forces of the electric fields, the adhesion forces can be very strong, making the contaminants difficult to remove. Contrary to popular belief, neutralizing the web will not make the particulate drop off. Due to the effects of field suppression, the electric forces at the intimate point of contact between the particle and the surface of the web cannot be broken. In this case, more elaborate web cleaners must be used where the particles are mechanically agitated from the surface, charges neutralized and vacuum employed to evacuate and collect the debris. If the web can be maintained at a near neutral state throughout the transport system, the web will remain much cleaner and the requirement for web cleaning may possibly be avoided.

Induction Charging

When an ungrounded conductor such as a metal machine part, nearby metal object, or the human body is within the range of an electric field from a charged surface, it too can become charged. This is known as induction charging. This inductively charged object or body subsequently coming close to or touching another conductor will experience an ESD event whereby the charged object will discharge to the other conductor.

A common example of this is operator shocks when touching the machine frame or console. An ESD event can also cause RFI (Radio Frequency Interference) which can cause malfunction in the logic of modern electronic machine controls. As mentioned earlier in this writing the sudden discharge of a conductor in the vicinity of solvent rich vapors can be catastrophic.

Strong electric fields can also induce unwanted signals into unshielded input and output cables and enclosures disrupting electronic controls.

NEUTRALIZING CHARGES ON THE FILM WEB

If static charges on the film web can be controlled to a low level, most electrostatic related problems can be eliminated. A neutral material will have no electric field so induction charging, particle attraction and most ESD events will not occur.

Unlike conductors, charges on insulative materials cannot be neutralized by simply grounding. Methods such as modifying the surface of the material to give it some degree of conductivity or the use of air ionization must be employed.

Humidity

Raising relative humidity is sometimes used to increase surface conductivity of some normally insulative materials in an effort to reduce static charging. This can be effective on hygroscopic materials such as cotton fabric webs or uncoated paper webs. Typically, relative humidity should be approaching 55 to 60%. Success in controlling charges in this manner will be dependent upon relative humidity, temperature, ability of the surface to absorb moisture and the process speed.

Since films are non-hygroscopic, higher humidity levels may result in a reduced level of charge generation but seldom eliminates the problem.

Internal and Topical Antistats

Antistats are chemical ingredients added to the formulation when extruding some types of plastic films or may be applied to the surface of the film by misting or coating. The surface resistivity of the normally insulative material is typically lowered to the range of 10^7 to 10^{12} ohms/square making it semi-conductive, which reduces tribocharging and provides a path for accumulated charges to dissipate to ground.

Depending upon subsequent processes and the end use of the material, the use of antistats may not be appropriate. Most leave somewhat of an oily residue on the surface which may be a contaminate to coating or printing and are humidity dependent. FDA approval may also be an issue. The added cost to the product should also be considered.

Ionization

The use of air ionizers is the most common, cost effective method of controlling static charges on the film web. Ionizers emit vast quantities of both negative and positive charged gas molecules called air ions. The ions are made available to the charged web where the electric field attracts the necessary ions of opposite polarity to its surface, thus balancing the charge on the web. See Figure 6.

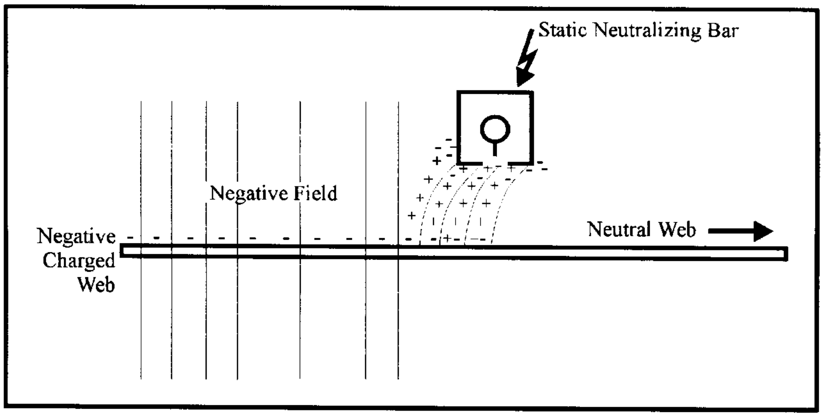

Figure 6
Field from Charged Film Web Attracts Opposite Polarity Ions from Static Bar, Neutralizing the Web.

The most common ionizers used in film transport systems are static bars and ionized air blowers. They may be electrically operated, passive, or may use radioactive materials as the ion generation source.

A typical static bar has an optimum working distance of about one inch. Some extended range type bars can be effective up to several inches, depending upon the intensity of the charge and the geometries of the application. In applications where greater ionizing range is needed, forced air is utilized to propel the ions to the target surface. This may be in the form of a compressed air tube or air knife coupled to a static bar or may be a blower/fan arrangement with an ionizing source.

The ionizer should be positioned just ahead of the problem area and must treat the web where it has air space on the opposite side. It should not be positioned over an idler roll or where the web is against another surface or the field suppression effect will prevent effective neutralization. In most cases the web can be neutralized from either side so when using static bars, they may be placed where they least interfere with rethreading the web.

TYPICAL APPLICATIONS IN THE WEB TRANSPORT SYSTEM

Unwind. High charges can develop as the film parts off the unwind roll. This is especially prevalent with high speeds and tightly wound rolls.

A static bar should be positioned just downstream of the first idler roll provided it is relatively close to the unwind roll. If there is a long span of several feet to the first idler and contamination or safety is an issue, an extended range static bar or ionizing blowers should be used. The bar should be looking at the web three or four inches downstream from where it parts off the roll. The bar should have an effective range capable of handling the fluctuations in the web path due to changes in roll diameter. If ionizing blowers are used, ideally, they should be positioned to blow into the nip point where the film parts from the roll.

Nip Rolls. Nip rolls are high charge generators as they exert considerable pressure against the web to facilitate pulling the web through the process. A static bar should be located immediately downstream of the rolls and should be positioned on the same side as the rubber roll.

Idler Rolls/Bow Rolls/Accumulators. Film contacting two or three metal idler rolls may not generate significant charges on some films; however, the generation of static electricity is an additive process and contact with several idlers such as those found in accumulators can result in high charges. A static bar may be positioned where the web exits this section or high volume ionized air blowers or air assisted static bars may be positioned to deliver the ionized air directly into the accumulator from the outside edge of the web.

Bow rolls and idler rolls with insulative sleeves or coverings such as teflon, cork, polyethylene, rubber, etc. are high charge generators. A static bar should be positioned just downstream and on the same side of the web as the roll. If it is desirable to also neutralize the surface of the roll covering, the static bar can be pointed into the nip of the roll on the downstream side as show in Figure 7.

Corona Treater. Most films exiting a high voltage corona treater tend to exhibit significant charges. If attraction of particulate to the web is of concern, a static neutralizing bar should be installed just downstream of the corona treater.

Coating Heads. The web approaching the coater should be as static free as possible. A static bar should be located at the web where it enters the coater section. Care should be taken to locate the bar so that coatings will not drip or mist onto the bar rendering it ineffective. Since this is a hazardous area, all ionizers in the area should be rated for Class 1, Division 1, Group D environments.

If the coating rolls regenerate the charge, an ionizer should be used where the web parts from the coating nips. If a high field intensity exists here, arcing could occur. A static bar mounted here, 1 to 2 inches from the nip may tend to become coated. The bar can be fitted with air assist and mounted 4 to 10 inches downstream with the air flow directed into the nip. An alternative would be an ionized air curtain transvector or ionized air blowers mounted 1 to 2 feet downstream blowing into the nip point.

Winder. As a charged web winds up on itself, its electrical capacitance increases as its diameter grows. The roll has the ability to store tremendous electrical energy and is a source for induction charging and hazardous electrical shocks to the machine operator. The electric field may reach out several feet and will attract particulate to the surface of the roll.

On standard reel-type winders, a static bar should be mounted after the last idler roll at the winder. Depending on core size and maximum roll diameter, an extended range type static bar or air assisted ionizer may be required to compensate for the fluctuations of the web path.

If the winder utilizes a lay-on roll, especially rubber covered, high charges can be generated on the material roll. A standard static bar may be mounted on the lay-on roll support arms and positioned at the required distance from the film roll. As each layer of film winds onto the roll, it passes under the bar and the charge is reduced. (See Figure 8.) An alternative is to use air assisted ionizers and blow directly onto the film roll. These methods are not optimum due to a degree of field suppression; however, satisfactory results can be achieved.

Surface winders require a similar approach using air assisted ionizers on non-airflow extended range ionizers treating the film roll as it winds up.

With some turret winders, depending upon their design and the maximum film roll diameter and web path fluctuations, a standard or extended range static bar may be placed just after the last idler roll. If this is not possible, an extended range static bar or air assisted ionizer may be needed to treat the film roll itself.

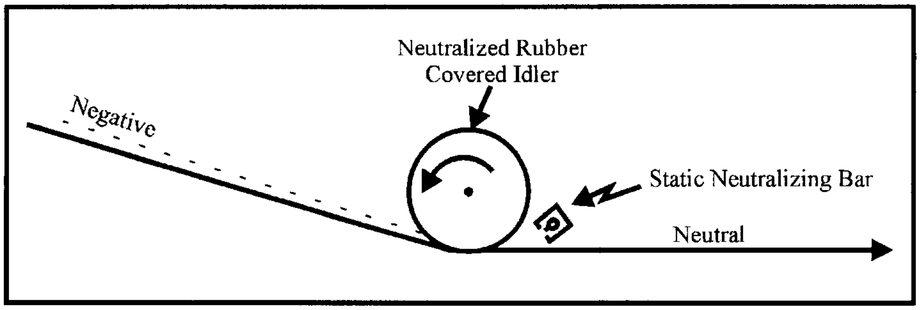

Figure 7
Static Bar Positioned to Neutralize Both
Negative Charged Film and Positive Charged Idler Roll.

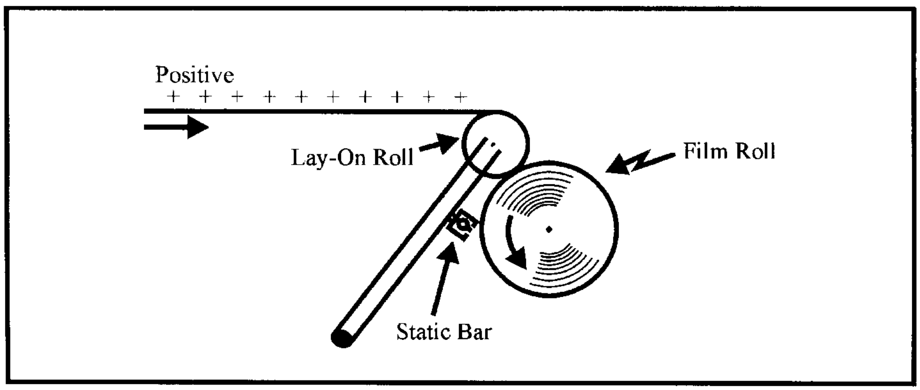

Figure 8
Static Neutralizing Bar Mounted on Lay-On Roll Support Arm
to Neutralize Film Roll.

SUMMARY

Significant electrostatic charges develop on the film web as it unwinds from itself and comes into contact with various components of the web transport system. Problems associated with static charges may be safety issues such as operator shocks or fires in coaters. Static charges on the web also attract particulate and may also result in non-uniformity of coatings resulting in poor product quality and rejected materials.

Ionizers are commonly used to neutralize static charges on the film web. They emit both negative and positive air ions and make them available to the surface of the web. The field from the charge on the web attracts the ions of opposite polarity and the charge is neutralized. With proper positioning of ionizers in the transport system, static charges can be controlled throughout the process.

A neutral web will stay cleaner, enhance safety and result in increased production of a higher quality product.

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