Corona Treating Covering Technology and Innovation: Part 1
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TYPES OF COVERINGS:

Rubber and Silicone:
The first corona treater roller coverings were made from rubber compounds: Hypalon (now called CSM – chloro-sulfonated monomer) and silicone, typically in the 70 Shore A durometer range. These coverings provide adequate levels of corona treatment and resistance to heat and ozone, but are easily cut and abraded, especially silicone. CSM also has a variable resistance level due to its sensitivity to the relative humidity level. Both materials can be eroded (oxidized) by ozone and by long term direct exposure to the corona, which can produce an uneven or grooved coating surface. Cover thicknesses are in the 125 mils range for CSM and 100 to 200 mils for silicone depending on roller size. Both materials have a good coefficient of friction to the web.

Epoxy and Thermosets:
Harder thermoset coatings, epoxy, polyester, and glass composite materials, generally called epoxies, are the second generation of corona treater coverings. These materials are much harder, in the 80 Shore D range, and are very resistant to cuts and abrasion and have stable electrical properties. Thermosets are still vulnerable to chemical attack when exposed directly to ozone and the corona, which will oxidize all organic materials in the covering and leave inorganic components behind as loose powder. Epoxy cover thicknesses are in the 125 mils range.

Glass Covering:
The glass covered corona treater roller was introduced in the 1970's by Pfaudler, a maker of glass-lined chemical vessels. Glass coverings for corona treaters are made of borosilicate glass (BS), also known as Pyrex, and by other brand names, for heat and shock resistant glassware. It is a fused, non-porous material, and does not require a porosity sealant. Borosilicate glass is primarily silicon dioxide and boron oxide with several other metal oxides. As such, it is extremely resistant to oxidation. BS glass is thermally shock resistant owing to its low thermal conductivity. Because of its relatively low thermal expansion rate and high fusing temperature, low thermal expansion alloys are required for the roller cores. The cover thicknesses are similar to ceramic at 60 to 80 mils. BS glass is an excellent dielectric material and nearly as hard as ceramic, but not quite as impact resistant. The minimum surface texture is similar to ceramic in the 15 micro-inches Ra range.

Ceramic Covering:
The ceramic corona treater cover was developed by Pamarco Inc in the early 1980's (1983 US Patent 4,402,888). The patent describes a plasma sprayed aluminum oxide (alumina) coating sealed with various organic materials to fill the small amount of porosity in the coating. Alumina is very cut and abrasion resistant and is usually harder (Rc 55-60) than a steel knife blade. The inert ceramic surface will not erode due to direct exposure of the corona, although the sealer can be affected somewhat. Alumina is very thermally conductive and can be effectively air or water cooled. Because of this, the allowable corona power level is typically twice that of organic coverings for the same roller dimensions. Cover thicknesses are typically from 60 to 80 mils.

PHYSICAL AND ELECTRICAL CHARACTERISTICS OF COVERINGS:

Dielectric Strength (DS) Defined:
Dielectric strength is the voltage required to penetrate a given thickness of defect free insulator and is the most basic property of a corona treater roller cover. The DS of the corona covering must be maintained at a level higher than the applied peak voltage by some margin or safety factor. Any defects, metal, or air inclusions in the coating also serve to reduce the DS. The DS value is usually expressed as either volts per mil or kilovolts (kV) per mm. So the DS of a roller cover is the DS of the material multiplied times its thickness.

Variability of Dielectric Strength:
The DS of a material is not a constant, but changes over time as a result of wear, surface oxidation by the corona, and heat aging, the combined effects of time and temperature. The DS of most materials also drops temporarily as the temperature of the material increases. That is why it is important for a corona treater cover to have an initial DS that is well above the peak voltage applied to it.

Dielectric Strength – Actual versus Published Values:
A large number of dielectric strength tests taken over an entire roller cover would yield a statistically significant data set, a bell curve with mean, maximum, and minimum values. For most measurements it is reasonable to state the mean and the standard deviation. For DS on corona treater rollers, the most important number is the minimum because that is where the coating will most likely fail.

Roller covering manufacturers generally specify the average DS of their corona treater coverings, and in some cases, even the high end of the range. In addition, the DS is listed as volts per mil not as the DS of the full thickness of the coating. DS testing is normally done on thin sections of material so that the voltages are within a reasonable range. The DS of the full thickness coating is then a calculated value with the assumption that the DS does not change with thickness (not generally true). The published DS values can be a little misleading when trying to compare various corona treater coverings.

Corona Environment:
Voltages from present day corona generators, at the electrode, are typically in the range of 10-12 kV (kilovolts) RMS. The voltage output only varies about 10% or so from minimum to maximum wattage. This means the peak voltages will normally be around 17 kV, or somewhat higher due to transient voltages (we will use 20 kV peak for the sake of discussion).

Cover Thickness Variation:
The cover thickness can vary because of the combined effects of the TIR (total indicated run out – or eccentricity) and taper (variations in diameter) in both the core and the cover. Even the most precisely ground hardcoat coating will have at least a few mils of thickest variation due to variations in the core and the grinding process. Of course, the DS of the cover will normally be the lowest where the cover is the thinnest.

Power Density:
Power Density or power rating is the level of continuous wattage that the corona roller cover can safely handle. The unit is square inches per kilowatt (the inverse of watts per square inch) and only accounts for the area of the roller actually exposed to the corona. The roller power rating is really about the average running temperature of the cover, which affects both its physical and electrical properties.

Corona treater stations are designed with air cooling to cool the metal or ceramic electrodes or to scavenge ozone, not specifically to cool the corona treater roller. The corona roller can be cooled separately, but this is not normally done unless the roller is water cooled to permit higher power levels.

Rubber and epoxy coverings are typically rated at 500 square inches per kilowatt (2 watt/sq. inch), while ceramic is rated at 200 to 250 (4-5 watt/sq. inch) and silicone is somewhere in between. Glass is rated at 200 (5 watt/sq. inch).

The determining factor is how much heat is being produced or absorbed by the covering and how much is being taken away by cooling, so that the cover temperature runs in a range that does not significantly reduce its physical and electrical properties.

CSM, epoxy, and silicone are relatively difficult to cool due to low thermal conductivity limiting the power that can be applied. Silicone naturally runs a little cooler resulting in a power rating higher than rubber or epoxy. Glass runs cooler than ceramic, but ceramic is easier to cool, so the power ratings are similar. Heated webs

generally treat a little more easily than cold ones, but nowadays, the stretching of thin films is a concern. It's better in most applications for the corona treater roller to run as cool as possible.

Dielectric Constant (Capacitance) of the Corona Cover:
The dielectric constant of an insulator is a measure of its ability to increase the volume of electric charge held in a capacitor compared to air. A basic capacitor is composed of two parallel metal plates of equal areas that are spaced with a given air gap between them. The capacitance increases with the plate areas or as the gap decreases.

The plates are connected to a precise voltage source (one positive, one negative) and the volume of charge that accumulates on the plates is measured. The air gap is then filled with the material to be measured and the process is repeated. If the volume of charge is doubled compared to having air between the plates, then the dielectric constant of the unknown is 2, since air is assumed to be 1.

The corona electrodes and treater roller form a capacitor with the roller cover as the dielectric (insulator). There is an air gap between the electrode and the roller cover, but this gap behaves like part of the electrode when the corona is present.

A corona treating system is a high frequency A/C circuit containing both inductance (high voltage transformer) and capacitance (electrodes, roller, and cover). These quantities need to be balanced in order for the generator to operate at a high power factor (efficiency).

These are the approximate dielectric constants (DC) of CSM rubber (5-6), silicone rubber (3-4), epoxy (5-6), glass (5), and ceramic (10). The capacitance of a corona treater roller is proportional to the area of the corona electrode, the dielectric constant of the roller cover and inversely proportional to the thickness of the cover. For example, a ceramic covered treater roller with a 60 mil thick cover and a DC of 10 would have 4 times the capacitance of an epoxy covered roller with a DC of 5 and thickness of 120 mils.

The roller capacitance affects the size and surface area of the corona electrode, so that a lower capacitance roller uses a larger area electrode and higher capacitance roller uses a smaller area electrode. This is done so that the total system capacitance is within the equipment's design limits.

A high capacitance roller should not replace a low capacitance one (ceramic in place of silicone for example) without consulting the manufacturer of the generator. Adjustments may need to be made (electrode area, output transformer, etc) depending on the generation of the equipment. Without the proper adjustments, the system may not operate efficiently. In the worst case, the roller and the generator can be damaged.

The capacitance of the roller also affects the quality of the corona treater discharge. Generally speaking, higher capacitance roller coverings will provide better energy distribution and corona treatment results.

Surface Ignition by the Corona:
If the corona treater roller stops rotating while the corona generator is still running, rubber and epoxy coatings will start to burn on the surface within a few seconds. Silicone rubber is not technically an organic polymer, since it has a silicon rather than a carbon backbone. As such it will survive a stopped roller a little longer than a normal rubber compound. The hardcoat materials, ceramic and glass, will not ignite under normal circumstances, but may crack if the local differential covering temperature gets high enough.

Effect of Coating Porosity:
Rubber and epoxy coverings frequently contain visible air bubbles as a result of the processing methods used to fabricate the coatings. Gases anywhere between the corona electrode and the grounded roller core will ionize (become electrically conductive) when passed through the corona forming region. This means that air bubbles

in the treater coating will behave no differently than bits of metal of the same dimensions. This phenomenon in effect reduces the thickness of the covering in localized areas and may lead to dielectric failure (pin holing). The small amount of uniform porosity in plasma sprayed ceramics does not have the same effect, because the porosity has been filled with an insulating sealant. Porosity at the surface of a ceramic coating is just a component of the surface roughness.

Maximum Operating Temperature of Various Roller Covers:
Increasing temperatures normally reduce the DS, and cut and abrasion resistance of rubber and epoxy materials. Long term exposure to higher temperatures may also cause degradation of the material in terms of increasing hardness and loss of physical properties. The DS of ceramic and glass are affected by temperature to a lesser degree and the permanent effects are also smaller in magnitude.

Backside Treatment:
Backside treatment is caused by air under the web that ionizes when it passes by the electrode, corona treating unintended areas of the web. This is at least a waste of corona energy and may actually prevent the top side of the web from reaching the intended dyne level. In the worst case, backside treatment can cause other effects such as a vacuum metalized coating transferring to the backside of the web once the material has been wound up.

Surface texture on the corona treater roller can be rough enough to trap air under the web. On rubber coatings, a certain amount of surface roughness will be compressed by web tension squeezing the air out the region of treatment. Harder roller coatings need to be finished to lower Ra levels to prevent air entrapment. A surface texture of 30 micro-inches Ra is generally low enough to prevent backside treatment. 15 Ra is required for the most critical applications.

The build-up of slip agents and other surface contamination on the roller surface is the most common cause of backside treatment. These lift the web off of the roller, at least in localized areas, and allow air under the web. Wrinkles and blisters have the same affect.

Cuts, abrasions, and erosion will produce an uneven surface on the roller covering that traps air beneath the web. Erosion is chemical attack of the roller coating caused by direct exposure to the corona discharge. As a highly oxidizing environment, the corona converts organic materials, polymers and other materials, in the roller cover to mainly carbon dioxide and water. The net effect is no different than physical abrasion that creates low areas or grooves in the roller cover.

Humidity can be directly absorbed by a CSM rubber cover which lowers its resistance. Other than that, the predominant effect of humidity is to produce backside treatment when porous coverings are used.

Corona Treating Covering Technology and Innovation: Part 2
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THE EFFECTS OF STATIC ELECTRICITY:

Static charges are produced when any two dissimilar materials come in contact, and the effect is enhanced by friction. When in contact, charge transfers take place based on the chemical structure of the materials. One material will be charged positively and the other negatively to the same degree.

Static will be held on the material's surface or dissipated depending on the bulk resistance (resistivity) of the material. Dielectric materials (really good insulators) can hold static for minutes or even hours, and at dangerously high voltages. When the humidity is high, static charges are still formed but they tend to dissipate much more quickly than under drier conditions. Static is a danger to personnel and can also damage webs and roller coatings and cause web handling problems.

Most plastic films are good insulators, unless they are metalized or contain conductive additives. Polyester film, in particular, easily generates and holds high levels of static. Static, as the name implies, is electrical charge that cannot move. Webs are two sided and can hold a different static charge on each side. If the polarities (positive or negative) of the two sides are the same, the voltages will be additive, otherwise the electric fields will cancel each other to some extent.

Under the right conditions, voltages of 100,000 volts or more can be produced, even at relatively low line speeds. When the corona generator is running, static voltages are limited because the corona will absorb any excess voltage. When the corona generator is off, such as when the line is being webbed up, static voltages can sky rocket, especially if the web is sliding over the corona roller rather than turning it.

Corona treater rollers in an S-wrap configuration pose a particular static problem. Static produced on the bottom of the web on the first roller is carried to the second roller as static on the top of the web. Because the web and the roller surfaces are the same materials in both cases, the polarities of the charges on both sides of the web will be the same, making them additive. This means a lot of excess voltage is carried to the second corona roller, which is the one that typically pin holes due to static. The situation can be mitigated by making sure both rollers are turning during webbing up and by using passive (or active) static control devices such as static bars (induction bars), tinsel, and Static String (TM) acting on both sides of the web, and the roller surfaces in areas not covered by the web.

Voltage can arc between two pointed conductors at a level of about 15 kV per inch in air. This means that tinsel placed one inch from the web or roller surface will limit the surface voltages to no more than 15 kV, and probably less. Tinsel and other static devices are normally placed about one eighth of an inch from the charged surface so the maximum residual voltage should be less than 2 kV. Tinsel works better if it is not touching the surface to be dissipated. The air becomes ionized between the web and the sharp edges of the tinsel and the static charges leak through the air rather than arcing.

No corona treater cover can survive the extreme voltage levels static can produce. When a web, and/or roller surface, is charged to these extreme levels several pinholes can be formed in a roller cover at the same time. This is because a static discharge does not discharge the entire web, only the local area of the web near the discharge. Static will normally form microscopic pin holes in a ceramic covering. However, on a glass covering, little bits of glass can also be ejected from the surface if the voltage level is high enough. Static bars are required on glass rollers and are a good idea to be used on any type of corona treater roller.

PATCHING PIN HOLES IN CORONA TREATER COVERINGS:

When a corona treater roller pin holes, virtually all of the energy in the corona passes through the pin hole for a brief second. This may amount to several kilowatts of electrical energy. This amount of energy is enough to

burn or vaporize organic materials and to even melt ceramic (alumina = 3762 F). The arc may also bore into the surface of the metal core and blow vaporized metal back up through the pin hole leaving a thin deposit on the walls. A pin hole consists of a hole in the covering, usually not more than 50 mils or so in diameter, with conductive burned and/or melted material lining the walls of the hole. The material immediately surrounding the hole may also be degraded and compromised.

In order to make the best patch possible, all of the burned and compromised material has to be first removed and then the resulting hole cleaned and dried (e.g. alcohol) before patching. When the patching material is mixed, usually two part epoxy, some air is naturally also mixed in. Viscous, fast curing materials, like 5 minute epoxy, should be avoided because they entrain a lot of air during mixing, which does not have time to dissipate. Ideally, the mixed patch material should be placed in a vacuum in order to degas the material. The patch material should also be placed in the hole while under vacuum to prevent air from being trapped on the walls of the hole. The excess patch material can then be shaped to the roller with a piece of tape or ground to the right profile after curing.

The materials used to patch pin holes in corona treater roller are typically two part silicones and epoxies and fast curing methacrylate resins with spray-on accelerators. The same patching materials are used regardless of the type of corona treater cover being patched. Users generally want to get rollers repaired and back in service as quickly as possible. The patch needs to have properties which are equal to the rest of the corona cover in order to last a long time. This is generally not the case. The dielectric strength of high performance covers can be in the range of 1000 volts per mil. Patching materials are likely to be only 500 volts per mil at best, and that's if the patch does not contain porosity. As a result, the usually roller pin holes in the same location after a few hours, days, or weeks.

Any trapped gas bubbles in the patch material or along the walls of the hole will ionize in the corona and become conductive. This reduces the effective thickness and the dielectric strength of the patch. These are two primary reasons that patches fail after a short period of time.

A BREAK-THROUGH IN CORONA COVERING TECHNOLOGY:

Ceramic corona treater rollers have been used in the industry for more than 30 years and the properties and performance characteristics are well known. The typical ceramic covering is 60 to 80 mils thick (depending on vendor and product) and the initial dielectric strength values are in the 500-700 volts per mil range.

The breakthrough in technology that has resulted in the new proprietary ceramic product is due to a combination of materials and processes that have increased the dielectric strength to a level much higher than any of the component materials, a synergistic effect. In fact, the initial average DS level is 1000-1200 volts per mil (measured on the full thickness of the covering not a thin section), nearly double that of the typical ceramic corona treater roller and higher than any other available type of corona treater cover.

This new proprietary product has a significant safety margin above the typical applied peak corona electrode voltage of 20 kV, whether at 60 mils or 80 mils thick. Since dielectric strength generally decreases with the effects of time and temperature, this means that the product will maintain a good safety margin even after many years of service. It also means that the covering can operate at higher than normal temperatures (usually a result of increased power levels) if desired without compromising the dielectric strength.

The significant improvements in the new ceramic covering did not come at the expense of other product characteristics. It retains all of the important properties of ceramic coatings: high thermal conductivity; high capacitance; high hardness; cut, abrasion, impact resistance; smooth finish, tight dimensional tolerances, and ease of cleaning, and can be applied to either steel or aluminum roller cores.