Optimizing Blown Film Line Layouts

– For Improved Surface Treating Performance -

In today's race to produce film faster, thinner and with lower tension, reliable surface treatment is critical for success. There are a number of different philosophies employed when setting up a blown film line. Variables such as budget, available space, and specific application needs vary, but there are certain undeniable principles that can be used to ensure optimal surface treating success. This paper documents the best practices of blown film manufacturers ranging from multinationals to small privately owned operations. Learn about the latest trends and the do's and don'ts when optimizing your blown film line layout for improved surface treating performance.

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I. CORONA TREATING BASICS

A corona treating system, regardless of the type of electrode or roll covering, can be broken down into 3 major components: the power supply, the high voltage transformer, and the corona station which includes the electrode and the ground roll.

Corona treaters are basically devices that ionize air. They are used to treat the surface of non- porous substrates so that the liquid will wet the surface. Corona treaters form low molecular weight material on the film surface. Treatment oxidizes the film surface and forms positive or negative sites by adding and deleting electrons. This activity normally increases the surface energy or dyne level of a non-porous film.

Illustration 1 is of an ink droplet on untreated film versus an ink droplet on treated film. As you can see, if the substrate is not treated, the ink droplet will not wet. Instead, it will bead on the surface of that material as opposed to thoroughly wetting the surface.

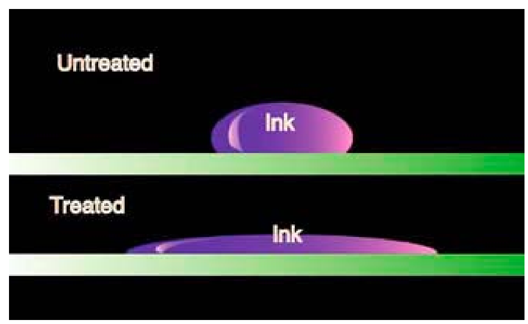

ILLUSTRATION 1

Corona Electrode and Dielectric Options

The style of electrode and its material is largely determined by your application requirements:

1. Type of film to be treated
2. Treatment of both sides or one side of the web
3. Line speed
4. Goal of treatment

The application specification determines which electrode, roll and power supply configuration will most economically meet the application requirements.

Electrode options:

1. Fixed width metal electrodes
2. Segmented metal electrodes
3. Fixed with ceramic tube electrodes

Fixed width electrodes with covered rolls are typically used in cast film lines. An advantage of this style is that corona is produced across the entire length of the electrode without regard to the width of the film going through the treater. The disadvantage is that any portion of the roll covering that is not covered by film is exposed to the corona. Depending on the type of roll covering that is chosen, this could be detrimental to the life expectancy of the roll covering.

Segmented electrodes are frequently used for blown film applications where lane treating is required. The advantage to this style treater is that operators can specify which areas of the film will be treated. They can also prevent the roll from being unnecessarily exposed to corona when running a narrower film. This system is dependent upon the operator to correctly position the segments in the treat or no treat position.

With metal electrodes, stainless steel is the preferred material. Stainless steel has thermal advantages and is more resistant to corrosion than aluminum. This is very important. Most segmented or fixed width metal electrodes problems are caused by thermal issues. When the electrode thermally expands, a change in air gap between the electrode and roll face can cause variations in treatment levels. Using stainless steel as opposed to aluminum reduces the opportunity for that variation and therefore provides you with a more consistent dyne level from edge to edge.

You should be wary of aluminum electrodes that have been anodized or coated to make them more resistant to corrosion. This can be helpful in the short-term, but the corona environment is very harsh and those materials simply don't last very well over time and will eventually wear off. So again, it is highly recommended to use a stainless steel electrode.

Maintaining Electrode Air Gap

As stated previously, most problems associated with metal electrode systems can be traced back to thermal issues which have created an inconsistent air gap. Creating thermal stability around an electrode increases your ability to maintain a consistent air gap. It is not uncommon for a corona treater to operate in the 80 – 90 degree C rate. At those temperatures, thermal forces will cause air gap changes resulting in inconsistent dyne levels.

Vintage equipment designs have no capacity for creating a concentrated airflow around the electrode. Illustration 2 shows a contemporary design that produces an exhaust airflow around the electrode to create thermal stability. In addition to cooling the electrode, the exhaust also removes ozone from the treatment area. Ozone is a by-product of corona treating which needs to be removed from the work environment.

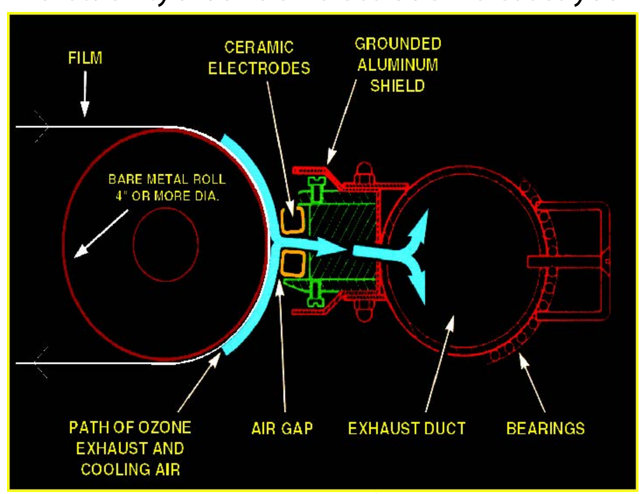

ILLUSTRATION 2

Electrode Air Gap Adjustment

In metal electrode systems, you'll want to have the ability to make fine adjustments and coarse air gap adjustment. The course adjustment is located at the end of the electrode assembly and can be used for initial setup. The nominal air gap distance between the face of the electrode and the ground roll for stainless steel electrode systems is going to be .060" or 1.5 mm.

When using aluminum electrodes many operators will set a very wide air gap in the order of .08", .10" or more. This is necessary because the thermal growth of the aluminum electrode would cause it to twist and potentially come in contact with the ground roll.

Modern corona treating systems and power supplies that have auto-load matching capabilities allow for a variance of +/- 10% in your air gap. Accordingly, you shouldn't experience any significant difference in dyne levels across a web direction within this range. For most applications it is recommended to set the air gap at .060" thousandths and leave it there unless you are treating something different, such as a thicker material.

New Remote Segment Actuation and Verification

Users of segmented electrodes recognize the common method of adjustment is to physically push the segment in for a no treat zone, and pull it out to activate an area of treatment as shown in Illustration 3. A new development in this area is the use of Smart Segments™ which can be remotely actuated and verified. This eliminates the need for operators to access the station to adjust segments and provides quality control verification that the segments are in the proper position for treating.

ILLUSTRATION 3

II. ROLL COVERINGS: PERFORMANCE AND LIFE EXPECTANCY

Softer materials like silicone and rubbers will generally fail quickly due to damage caused by knife cuts and other physical damage. However, those materials are more budget friendly than hard materials like ceramic and glass, which are not damaged by knives and razors. Damage to ceramic and glass are usually due to impact of some sort. In either case, whether you are dealing with the silicone rubber or hypalon covering or for that matter a ceramic or glass covering, if a pinhole develops a field repair method is similar without regard to which of those coverings you pick.

Before we compare dielectric roll coverings, let's consider the impact the design of the base roll will have on your operation. If the roll's core is not constructed properly, for example if the wall thickness is too thin for the length of the roll, the roll is going to deflect. If the roll deflects, the distance or the gap between the surface of the electrode and the roll is going to vary. That variance in gap will cause a variance in dyne level.

It's critical that the shaft, the core, and the headers of the roll are robustly constructed to prevent deflection which could result in the roll sagging under the electrode. If you are using a hard coating such as ceramic and the roll sags, you put undue stress on the ceramic, which may cause the ceramic to crack and fail prematurely. This is a preventable mechanical design failure. Always check with your dielectric coating supplier for recommendations on how the core should be designed for the type of material that will be used.

Common Dielectric Materials

Silicone has a benefit of being very durable relative to dielectric strength and can be very attractive from a cost standpoint. From an insulating perspective, it has a very good profile. The downside of silicone is that it's soft and frequently gets damaged due to knife cuts. It is also subject to other physical damage such as accidental contact with various tools. Once that happens, it's impaired and the minute you try to apply corona to it, it will arc to that spot and will need to be replaced. Table 1 compares the cost of dielectric coverings to the performance or wear resistance.

TABLE 1

Material	Cost	Performance/Wear Resistance
Silicone	Low	Basic
Epoxy	Moderate	Good
Ceramic	High	Better
Glass/Steel	Very High	Better

Epoxy is a resilient material. You can make cuts on it and while it may score, it typically won't cut through. Failure of epoxy is usually the result of time and environment. These roll coverings are exposed to an intense and harsh environment of heat, ozone and corona. An epoxy roll will generally last about six months under continuous use. From a cost standpoint, it's very inexpensive when compared to ceramics and glass.

One downside of epoxy is that it is not that great of an insulator. You'll find with epoxy roll treaters your ground roll diameters are sometimes going to be 30, 40 or 50% larger than a system with a ceramic or glass covered roll.

Ceramic and Glass coverings are similar in that they both have tremendous dielectric and insulating properties. They are extremely durable relative to corona exposure. Normally, these rolls only fail because of physical damage. This is very rare, but can happen accidently from someone dropping something on the roll, being hit by a hammer or some sort of physical failure where a chip occurs. If it becomes chipped or cracked, then the dielectric covering is compromised and ultimately the covering will need to be replaced.

The downside with both ceramic and glass is cost. Both are going to be more expensive. In the case of glass, you are also going to have a specially constructed core that has to be used to facilitate applying the glass to the core. That being said, both of them are very, very durable, both of them have a good longevity, both have very long warranties compared to the other types of coatings and both make very good selections.

Dielectric Operating Ranges

Silicone coverings can operate in the 350-450 sq in/kW range and usually have a thickness of .125". As the kW requirement of your application increases, the diameter of the roll must increase at a proportional rate to the coverings capabilities. Larger diameter rolls add cost, but the bigger the diameter of the roll, the longer the roll covering will last.

Ceramics and glass have a much higher dielectric strength. They can operate in the 250-300 sq in/kW range (200 sq in/kw in some conditions). Therefore, those coatings are far more durable and they are less likely to be damaged due to some physical impact. The fact that these materials have a thinner dielectric provides an additional benefit. The power supplies for these electrodes will operate at a different voltage because of the thinner dielectric – which provides less resistance.

Maintenance Extends Roll Covering Longevity

Try to keep the roll surface as clean as possible. If you allow melted poly or other debris to fix itself to the roll covering, over time those organics are going to turn back to carbon. Carbon is a conductor and corona will always go to the path of least resistance. Corona will continue to arc on the carbon spot on the treater roll until it ultimately creates a weakness in the dielectric and cause the roll covering to fail.

Never use a metal brush to clean an insulated roll covering. Metal brushes will clean the spot, but in the process, you will imbed little bits of metal into the surface. When that happens, you'll see little lightning streamers that hit the residual metal pieces and that will create hot spots on the roll which will eventually cause failure. Always use a non-metal component to remove that sort of debris from the surface of the roll covering.

Can my roll covering handle more power?

Over time, your application requirements may change and you may want to run your line faster. For example, if you have a 6 inch diameter roll and you want to run the line faster you might be tempted to replace your 5 kW power supply with a 10 kW power supply. If you don't check with your suppliers first, you may overpower the roll. If overpowered, you will shorten its life and the roll will fail because you have exceeded its rated capacity.

III. WATT DENSITY AND ITS RELATION TO DYNE LEVELS

The ultimate goal of any surface treatment system is to increase surface tension measured in dynes, which then increases the wettability and adhesion characteristics of the surface. This allows you to add value to the substrate through printing, laminating, coating, etc. Corona treating systems achieve this by applying a given level of power over a certain period of time to the surface. This power/time parameter is measured in watt density, which is defined as watts/ft2 (or m2)/minute.

Watt Density Formula

$$\frac{\textbf{Power Supply Output (watts)}}{\textbf{Electrode Width(ft or meters) * Line Speed(ft/min or meters/minute) * Number of Treat Sides}}$$

Although watt density applied is directly related to increases in dyne level (surface tension), the relationship is not linear, and the relationship is dependent on system and material parameters.

System Parameters

Applied watt density is directly proportional to power supply size in watts and inversely proportional to station size (web width). Therefore, if the web width is doubled, the power supply must be doubled to maintain a required watt density. This simple relationship is complicated by two factors: line speed and the capacity of the electrode to handle a given level of applied power.

All electrodes, whether wire, metal bar, metal shoe or ceramic covered, have an upper limit on the amount of power they can accept per unit length. If, to achieve a given watt density, the power supply kW increases beyond the electrode's maximum rating, either the electrodes need to be upgraded or additional electrodes must be added. Further, on a covered roll system an increase in the number of electrodes normally require an increase in treater roll diameter.

Line speed also complicates the sizing calculation. On a given system, the higher the line speed, the lower the maximum watt density that can be achieved. Being inversely proportional to watt density, line speed has a significant impact on system sizing and cost, which is why it's important to properly define your application.

Material-Process Parameters

The most obvious material-process parameters are the basic substrate material composition and the process being performed (extrusion, extrusion coating, printing, etc.) Their impact on corona treating sizing is increasingly complex.

The tables included show immediate problems as most materials are defined by a range of typical surface tensions. The ultimate surface tension and amount of increase are dependent upon the material's starting surface tension.

In addition, some materials, such as some polyesters, accept treatment readily and exhibit rapid increases in surface tension under relatively low watt density levels, say 0.9 to 1.2. Other materials, such as polyethylene, accept treatment less readily but will exhibit a significant increase in surface tension under moderate watt density levels, say 2.0 to 2.5.

Finally, some materials, such as polypropylene, are difficult to treat and may exhibit only moderate increases in surface tension under relatively high levels of watt density, say 2.5 to 3.0. Untreated materials can be completely unpredictable.

As a basic guideline, table 2 shows different types of materials and watt densities that usually create a desirable dyne level. For instance, if you are treating LLDPE in order to achieve approximately 42 dynes, you want to set your watt density to 1.5 to 2.0 watts per sq ft per minute. On materials like CPP, you are likely to need a higher watt density to achieve the same dyne level.

TABLE 2

Material	Watt Density	Dyne Level
LLDPE	1.5 to 2.0 w/ft^2/min	42 dynes
LDPE	1.5 to 2.0 w/ft^2/min	42 dynes
CPP	2.0 to 3.0 w/ft^2/min	42 dynes
BOPP	2.5 to 5.0 w/ft^2/min	40-42 dynes
BOPET	1.0 to 2.0 w/ft^2/min	50+ dynes

These watt density values are only a reference point and your own application data may vary. It is important to understand that watt density cannot be used to predict dyne levels. First of all, the relationship between watt density and dyne levels is not linear. Secondly, process parameters such as line speed, system parameters such as electrode type, and material parameters such as slip additives must also be taken into consideration.

Skip Treating and Pattern Treating

In some cases, you may have an application for skip or pattern treatment. A common application for this is in the manufacturing of gusseted bags that require heat sealing. You want to avoid treating the areas of the bag that will be heat-sealed. The best solution for skip or pattern treating is by employing a PLC based skip treat controller with touch screen controller. Once you set-up your bag length parameters and no treat zones it automatically calculates and controls the output of the corona treater to match your requirements.

IV. ALTERNATIVE SURFACE TREATMENT TECHNOLOGY OPTIONS

Stainless steel fixed width and segmented electrodes are well suited for most blown and cast film applications. However, high definition corona, atmospheric plasma and flame plasma offer unique capabilities.

High definition corona is produced by special equipment featuring a ceramic electrode and proprietary roll covering formulation. It is capable of generating corona at high power densities and produces homogenous corona for high treatment levels.

High definition corona treatment creates micro-scale surface roughness on organic substrates. As shown in Illustration 4, this roughness can be measured with atomic force microscopy (AFM). A close look at the AFM images consistently shows that high definition corona creates more surface area than conventional corona discharge systems. The increase in surface area translates into more potential bonding sites for inks, coatings and adhesives.

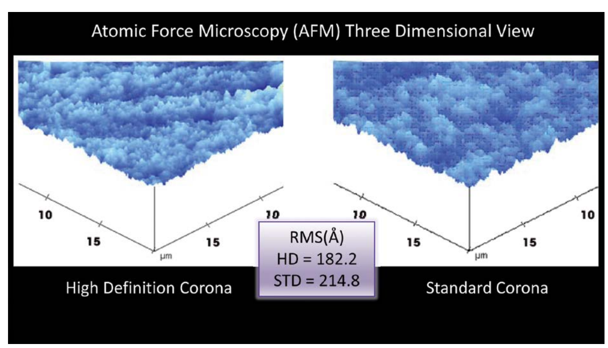

ILLUSTRATION 4

High definition corona systems also offer a number of operational benefits including minimal chance of roll burnout and added protection from pinholing, backside treatment and film wrinkling. High definition corona is widely used in converting, printing, coating and laminating applications. Because of the benefits mentioned above, these systems have also found a home in the cast film and blown film market for certain applications where lane treating is not required. For example, high definition corona is ideal for treating the inside of slit sheeting. Unlike segmented electrodes, you don't have to worry about an operator improperly adjusting the segments. You will always get full corona across the entire width of the ceramic electrode to treat the entire width of the film.

Atmospheric Plasma

Atmospheric plasma systems provide the ability to ionize supplied gases to create an extremely homogenous plasma discharge without filaments. Atmospheric plasma operates at low voltage and creates higher and longer lasting surface energy than corona discharge systems.

The surface effects produced by atmospheric plasma are profound. As reactive gases are diffused toward the surface under the influence of electrical fields, low molecular weight materials such as water, absorb gases and polymer fragments are knocked off the surface to expose a clean, fresh surface. At the same time, a percentage of the reactive components in plasma with sufficient energy bond to the freshly exposed surface, are changing the chemistry of the surface and imparting the desired functionalities.

A major advantage of atmospheric plasma is its proven ability to produce long lasting treatment results on low polarity materials that would be unresponsive to corona treatment, such as silicone or fluoropolymer substrates. The ability to clean, etch and functionalize surfaces makes atmospheric plasma a technology to consider when producing high value materials or materials that would be unresponsive to corona treatment.

V. TROUBLESHOOTING DYNE LEVELS FOR CAST AND BLOWN FILM LINES

It is strongly recommended that you use the ASTM test method as the basis for conducting your dyne test. Specifically ASTM D 2578-08 and the corresponding paper called Standard Test Method for Wetting Tension of Polyethylene and Polypropylene Film. This is the foundation or basis for which you should be conducting all of your dyne tests, specifically, if you are guaranteeing or promising a dyne level to an end user.

This is important because dyne testing is an extremely subjective test. Therefore, if it is subjective in your facility, you can be sure it is subjective in your client's facility; trying to get all numbers to match is going to be very difficult.

The second part of this is the fact that dyne level does not equal adhesion. This is very confusing to many people in the industry. It's understandable, as in most standard converting applications, as the dyne level goes up, the client's end result improves. The ink sticks better, the adhesive sticks better, the adhesive works in the manner in which they want it to. It is easy to get comfortable in assuming that 42 dynes gives good adhesion. However, 42 dynes doesn't give any adhesion, it is only a measurement of wetting.

So again, dyne level does not equal adhesion. Instead, dyne level measures the wetting level on the surface of the film.

Blame the Corona Treater

Here is a real world example of a dyne level problem between a film provider and converter.

"That film you sent me was supposed to be 42 dynes! I can't convert this stuff and I've got orders due!" exclaims the exasperated converter. "Hold on a minute, I'm sure we shipped you film that was 42 dynes. Let me look into this," contends the film producer.

When dyne levels are insufficient, it's a problem for everyone. And in most cases, finding the cause(s) is a bit more complicated than pointing fingers.

Since the corona treater is responsible for raising dyne levels, many operations will jump to the conclusion that there must be something wrong with the treater. Fortunately, it's pretty easy to tell if there is a problem with the corona treater. Nevertheless, before looking at the corona treater, think about the specific problem. In the above example, the film producer says their records show that they shipped film with a dyne level of 42. If that's true, then there are only a few possibilities:

- inaccurate dyne testing
- process inconsistency
- post shipment changes

As mentioned previously, it is highly recommended to use the ASTM guidelines for Meyer rod draw down testing with dyne solutions (Illustration 5). However, we recognize it is often more practical to conduct quick pass/fail tests with dyne pens. In either case, there is a subjective and interpretive nature to these tests, which can vary results several dynes, based on the person doing the testing. It is important to have consistent procedures in place to ensure accurate testing.

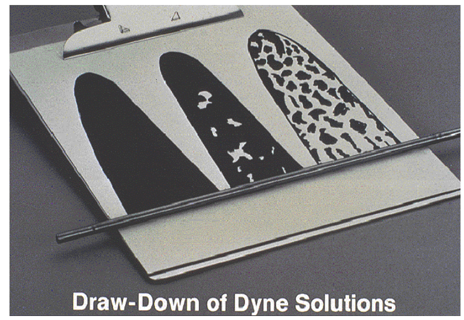

ILLUSTRATION 5

Process Inconsistency

Inconsistencies on the film line will create inconsistent treatment results. Consider that the treater is set-up to generate a specific watt density for the film and line speed to be processed. What are the variables that can affect the treatment results?

If you have a proven application recipe, (say a 1.5 watt density at 250 mpm producing a dyne level of 42 dynes) and you are getting a different dyne level result, the first thing to examine is changes in the resin. Have you recently changed resin suppliers? Has an additive been added or removed? These factors can affect your treatment results.

A less obvious cause can be variances in the temperature of the chill roll and its position relative to the treater. Warm film demonstrates a greater responsiveness to corona treatment. If the chill roll temperature is not properly maintained, treatment results can vary.

Post-Shipment Changes

Changes in dyne level over time are common. If film has been inventoried for a long period of time or exposed to environmental conditions, dyne level from corona treatment will decay.
Another cause of dyne level decay are additives rising to the surface. This can cause problems for the converter.

Why Smart Converters Bump Treat

With so many variables at play, it's no wonder that smart converters bump treat material as part of their converting operation. This provides them with the added insurance that the dyne levels are optimized for their specific process. The added control of in-line bump treating allows converters to respond to any dyne level issues on the spot. Instead of wondering if their film supplier is to blame, the converter is a happy customer running production.

What about the corona treater?
It is easy to determine if the corona treater is causing a problem with dyne levels. The most common problems are an improperly set watt density, an inconsistent electrode air gap, or an interlock failure that has turned the treater off. There is little doubt that troubleshooting dyne levels issues can be tricky; but with a better understanding of your process variables and a little help from bump treating, converters' dyne level problems will be a thing of the past.

VI. OPTIMIZING LINE LAYOUTS

Optimizing line layout in your cast or blown film line is equally as important as selecting the right equipment. When it comes to surface treatment on a blown film line, there are a number of different philosophies employed. Factors including budget, available space and specific application criteria all contribute to your ultimate decision. With today's race to produce film faster, thinner and with lower tension, it makes sense to optimize your treater set-up for the worst-case scenarios.

Treating the Outside of the Film

Upstream applications that require treatment of the outside of the film are fairly straightforward. The biggest challenge here is ensuring the nip roll prior to the surface treater is properly adjusted. If it is not, air will remain trapped inside the tube and backside treatment will occur.

A two-sided covered roll system with stainless electrodes works well for this type of application. Typically, a segmented electrode is used with either a ceramic, epoxy or silicone sleeve dielectric. If lane treating is not required, you can use a high definition corona system with ceramic electrodes.

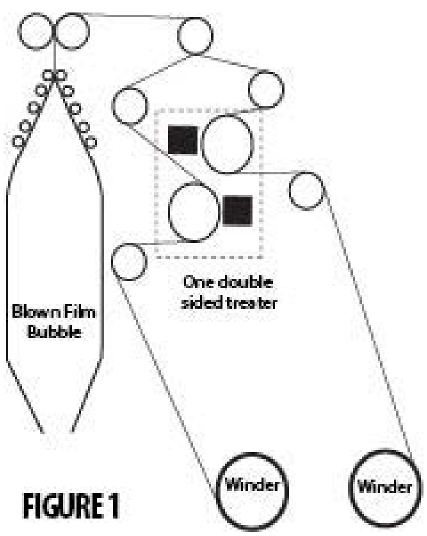

FIGURE 1

When treating either the inside or the outside of the film, it's helpful to realize that treating slit film is a much more delicate process than treating film in a tube format. Slit film requires careful handling as it has a tendency to wrinkle which will cause backside and uneven treatment levels.

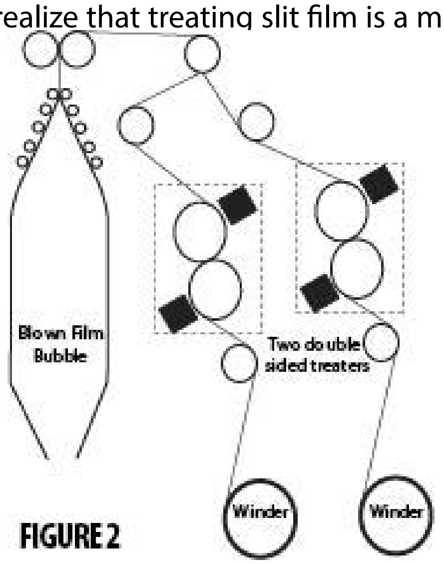

FIGURE 2

Figure 1 shows a layout designed to treat the two insides of a slit tube. This layout should be avoided as it creates a number of problems. It is extremely difficult for your operator to slit the tube and thread it through one treater station. In addition, thinner gauge material increases your chances of backside treatment which will result in uneven treatment on your film.

As shown in Figure 2, some companies create a complex web path for the substrate after slitting so they can utilize one additional two-sided surface treater. These web paths require multiple idler rolls and nip rolls, which add significantly to the cost and size of the station. Therefore, this concept is not desirable because of both cost and the potential for web handling issues that will cause backside treatment.

A cleaner, simpler and less expensive solution is shown in Figure 3. The first double-sided treater station is positioned right after your upper nip assembly or after your haul off to treat the two outsides of the tube. This way you are minimizing any chances of backside treatment on the outside. The best solution for treating the two insides of the slit tube is with two single-sided treater stations just prior to each winder.

As you can see from the web path, it makes it a lot easier for your operators to thread up. You get more wrap around the ground roll, which will then help minimize any chance of backside treatment. If cost is an issue, the two single-sided treater stations can be set-up with provisions to add a nip roll should any backside treatment issues occur. Backside treatment is often related to the type of film you are running through the corona treater station.

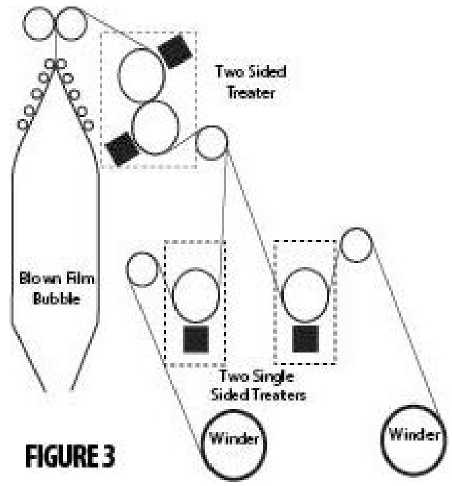

FIGURE 3

By using two single-sided corona treaters, your operators will be able to thread a simple web path. Most importantly, it allows the film to follow a relaxed natural path to ensure reliable treatment results.

In comparison, look at the previous layout with two double-sided treater stations. It has options to treat either the inside and/or the outside, which requires a nip roll to each roll. So, that means you have a total of four nip roll assemblies. In order to optimize web handling in this configuration, you will need a drive for each one of those rolls to give you the ability to adjust and eliminate any wrinkling between the two rolls. It is possible to do it with one drive and have an S-wrap configuration with your drive, but again, you won't have the ability to adjust the speed of each roll.

Using the three treater set-up in Figure 3 provides the easiest web path for your operators to thread, allows the film material to follow its most natural path, and reduces the size of the treating stations by minimizing the need for additional drives and nip rolls.

VII. SUMMARY

- Dyne level readings are subject to interpretation, follow ASTM guidelines for best results.
- Increased watt density does not equal increased dyne levels.
- Increased dyne levels do not always equal better adhesion.
- Dyne level effects from corona decay over time.
- If using metal electrodes- choose stainless steel over aluminum.
- High definition corona - minimizes potential for backside treatment, wrinkling and pinholing.
- Atmospheric plasma raises surface tension levels on the most inert, non-polar surfaces.
- Flame plasmas are for high-speed lines where boundary layer air interferes with treatment uniformity and where more stable surface energy is required.
- Smart converters bump treat to ensure optimal dyne levels.
- Slit film is more delicate to handle.
- Line layout is as important as equipment selection.
- A bad web path is more expensive than an additional corona treater.

To learn more about this topic, download our on-demand webinar ***Mastering Corona Treaters, Roll Coverings and Electrodes for Extrusion Film Lines.*** If you have any other questions, please contact Tom Gilbertson or Mario Leonardelli at (262) 255-6070 or visit www.enerconind.com.