The Corona Treatment of PP Polymer Films in Practice

Contents:

Explanation of concepts and definitions

Specific energy

This measurement identifies the corona dose to which a film is subjected. Included in it are the working speed, width and applied power.

Power density

This specifies the power per cm of discharge line. This information is important in order to assess the saturation effect of the discharge and, in my opinion, as an assessment criterion concerning the degree of thermal shock applied to the foil by the corona.

In the next pages, these concepts, which are used over and over in the following, are explained in the next pages through practical examples.

What does corona dose mean?

The is the specific quantity of electrical energy applied to the web material. Using this parameter, it is possible to calculate the increase in the surface energy or to dimension a corona treatment system for a particular application.

Example:

System and process data:

System width:	1600 mm
Number of sides to be treated:	2
Maximum film speed:	100 m/min
Max. generator power:	4.000 Watt
Type of electrode:	segment, with 3 discharge lines

$$\text{Corona dose} = \frac{\text{max. generator power}}{\text{max. speed} \cdot \text{width} \cdot \text{number of sides}} =$$

$$= \frac{4.000}{100 \cdot 1{,}6 \cdot 2} = 12{,}5 \text{ W min/m}^2$$

What does "power density" mean"?

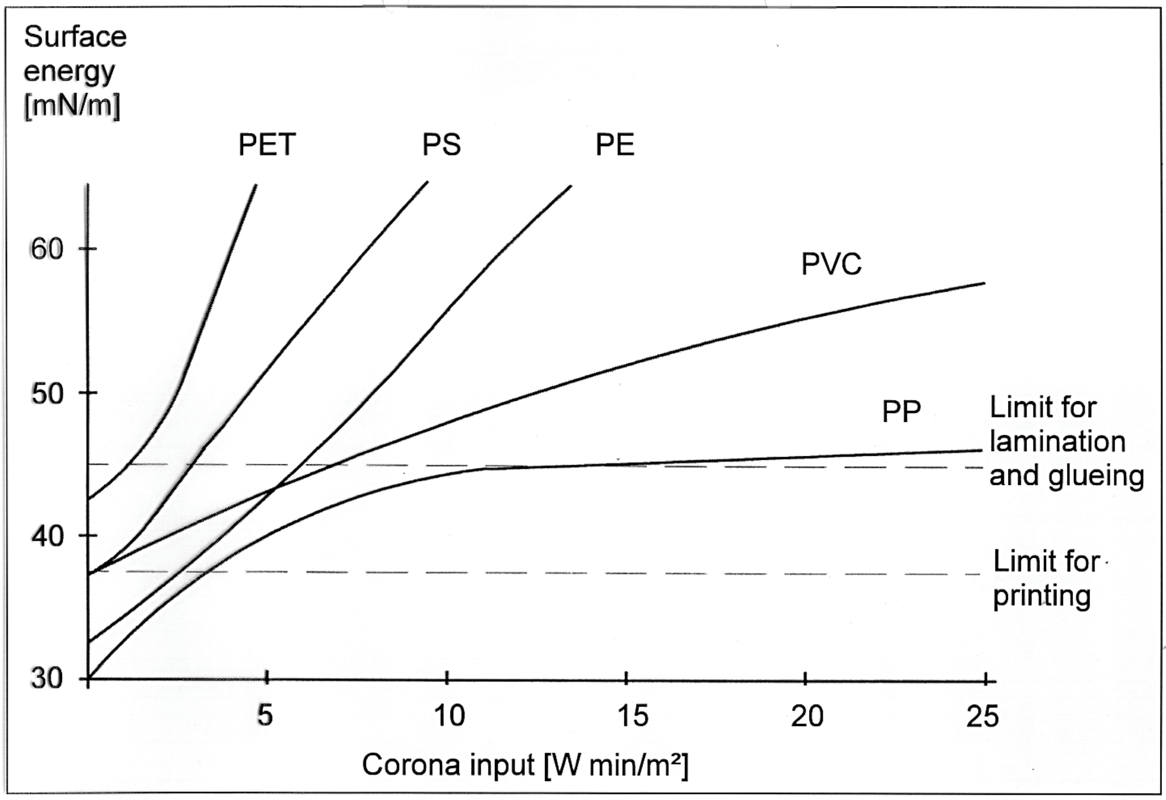
This is the specific power applied to a 10mm length of an individual corona section. Using this parameter, the effectiveness of a discharge can be assessed or a treatment station can be correctly dimensioned for a specific treatment application.

$$\text{power density} = \frac{\text{max. generator power}}{\text{width} \cdot \text{number of sides} \cdot \text{number of discharge lines}}$$

$$= \frac{4.000}{160 \cdot 2 \cdot 3} = 4{,}17 \text{ W/cm}$$

Treatability

Not all film materials can be equally well treated. The following diagram shows this treatability of different materials. This very impressively shows why a special role applies during the corona treatment of PP. Still, these curves can give only a rough overview. Within the classification “PP” or “PE” are many different formulas whose treatment behavior is strongly influenced by their ingredient components. In order to guarantee a specific treatment characteristic, one must either refer to exactly known and defined raw materials or must test the customer material in the laboratory.

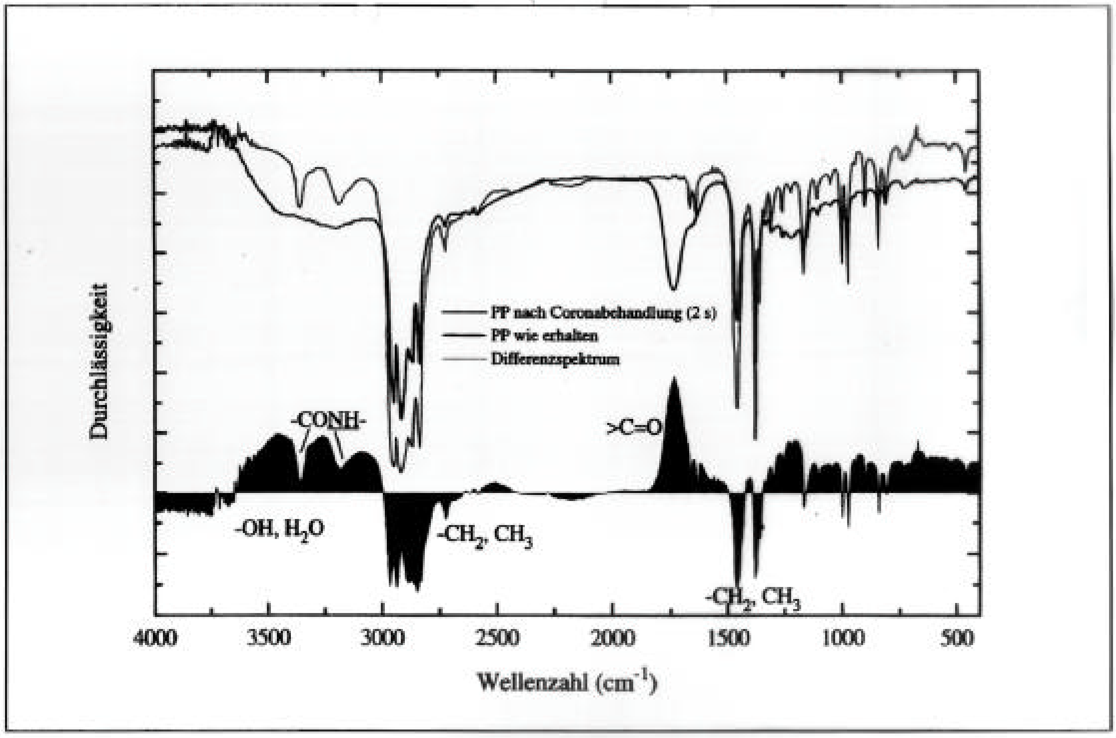


Treatability of different polymer films

It’s also good to know why PET, for example, usually doesn’t need to be treated for printing: the level of the surface energy in the untreated state lies clearly over the value needed for printing.

What happens during the corona treatment?

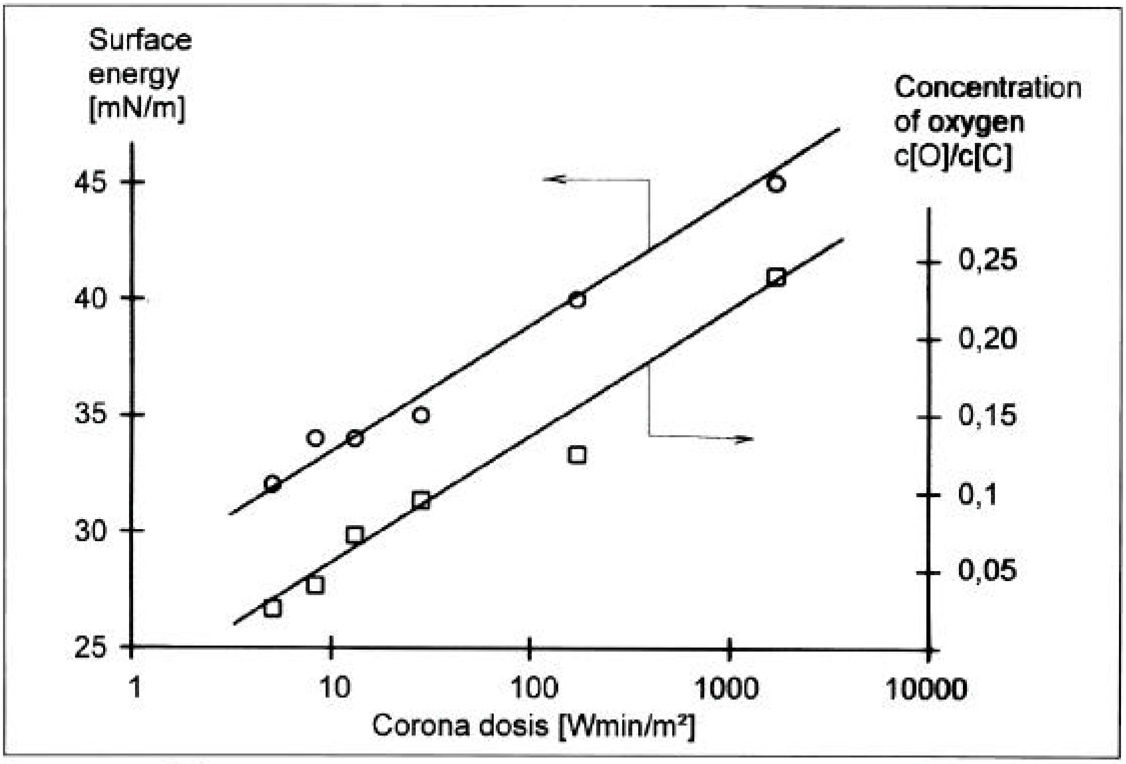
When observing the ATR spectra of untreated and corona-treated film, one recognizes in the differential spectrum that somewhere around wave number 1700 a new peak emerges which is typical for a carbon-oxygen double bond. This leads to the supposition that the existence of this C=O group (named carbonyl or carboxy group) is responsible for the wettability.



ATR-Spectra of PP before and after Corona treatment, incl. differential spectrum

In order to substantiate this supposition, the oxygen concentration in proportion to the carbon concentration was measured with reference to the applied corona dose. As it turns out, the wettability and the C/O concentrations correlate in extensive areas.

It should not be overlooked that the oxidation is probably only one part of a very complex and great variety of reactions. A corona treatment in a nitrogen atmosphere, where such oxidation is to a great extent excluded, also produces an increase in the surface energy, which shows that other reactive groups are also produced.



Increase of Oxygen concentration and wettability from corona treatment

Reverse side treatment, causes and remedies

Basically, air between the film and the roller is responsible for reverse-side treatment. This air is ionized in exactly the same way from the corona as the air on the front side. At the places in which air is trapped, a corona treatment of the reverse side takes place. The term “Break through" is somewhat misleading. These terms, however, are widely used, and are therefore mentioned.

There are different reasons for the air behind the film:

Venturi effect

Fast moving films also carry air masses along with them on the upper and lower sides. These force themselves onto every idle roller like a wedge between the roller and film. The same thing happens with the corona roller. A pressure roller, which forces the air out, provides one remedy. In some cases, an increase in the web tension can bring about the same effect. However, each individual case must be carefully examined to ensure that no new problems are created by doing this.

Indentations in the roller’s surface

As a rule, the corona rollers are coated with special silicone rubber. This silicone rubber has a relatively narrow elasticity range. This very easily leads to damage to the surfaces of the roller if insufficient care is taken when threading the film with the pull-in tape. Operation with a pressure roller is especially critical if the corona and pressure roller are not absolutely clean.
If grooves and dents in the roller are visible and tactile, the film no longer lies cleanly in these places, small insulating air cushions remain between the roller and film, and the effect mentioned above takes place. The only remedy here is a reworking of the roller ; in less serious cases, 0.2mm can be ground from the diameter, otherwise a new rubber coating is necessary.

Local overheating

Non-orientated PP tends to become wavy as a result of the high temperatures in the corona discharge. The pattern of this waviness typically has the following form: approximately 5 – 10 mm wide strips along the length of the machine, sometimes also slightly slanted, about 50 – 100 mm long. Distance between strips 10 – 30 mm, staggered along the length of the machine. These strips, which are slightly reminiscent of tear drops, are not immediately visible, but are to be recognized if the film surface is observed against the light. On the other hand, the waviness of the material means that the film lifts away from the roller in these places, with the results described at the beginning. The cooling of the treatment roller and/or the distribution of the power over a greater area, in order to reduce the local warming, can both be lead to an improvement. The correct adjustment of the parallelism of all electrode rails to the roller is also essential.

Indications for determination of the causes

Observation: the reverse side effect develops even at low power.

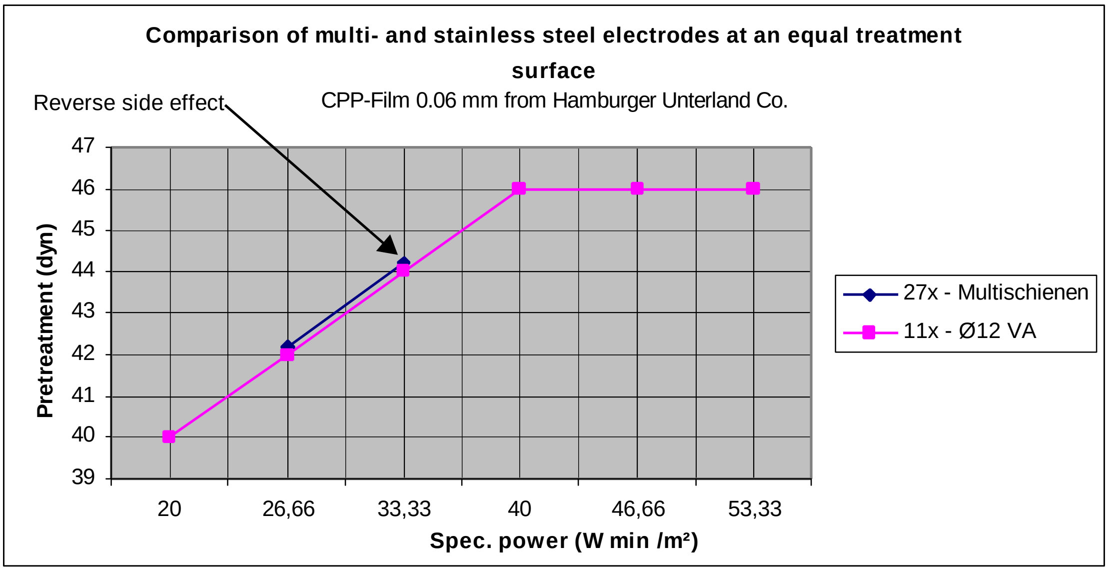
Cause: Venturi effect brings air behind the film, indentations in the silicone coatings

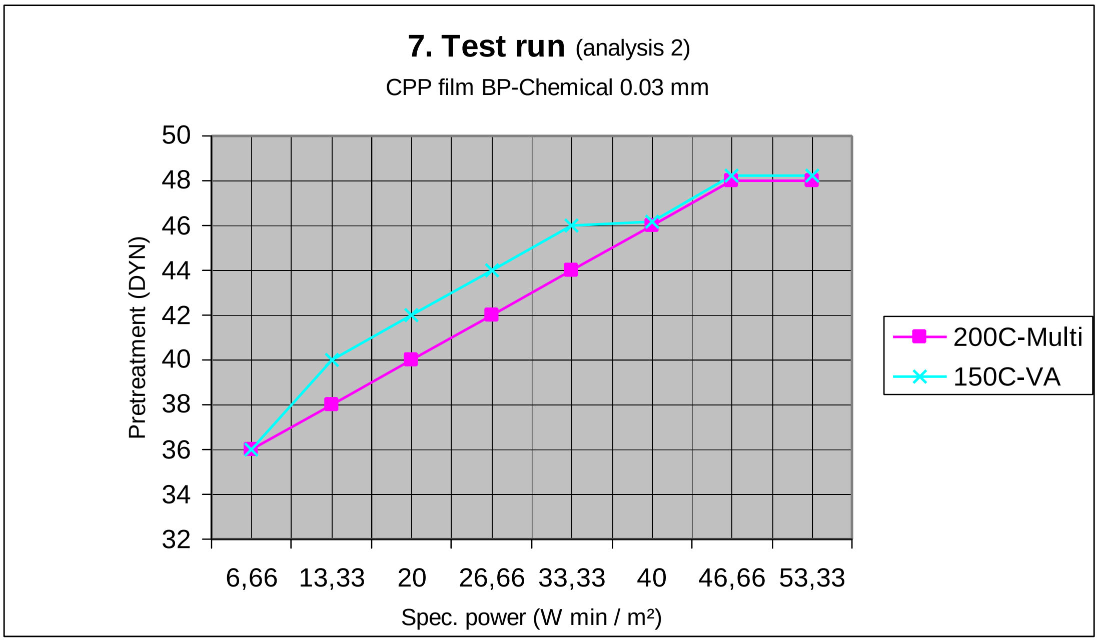
Observation: the reverse side effect first develops at higher power.

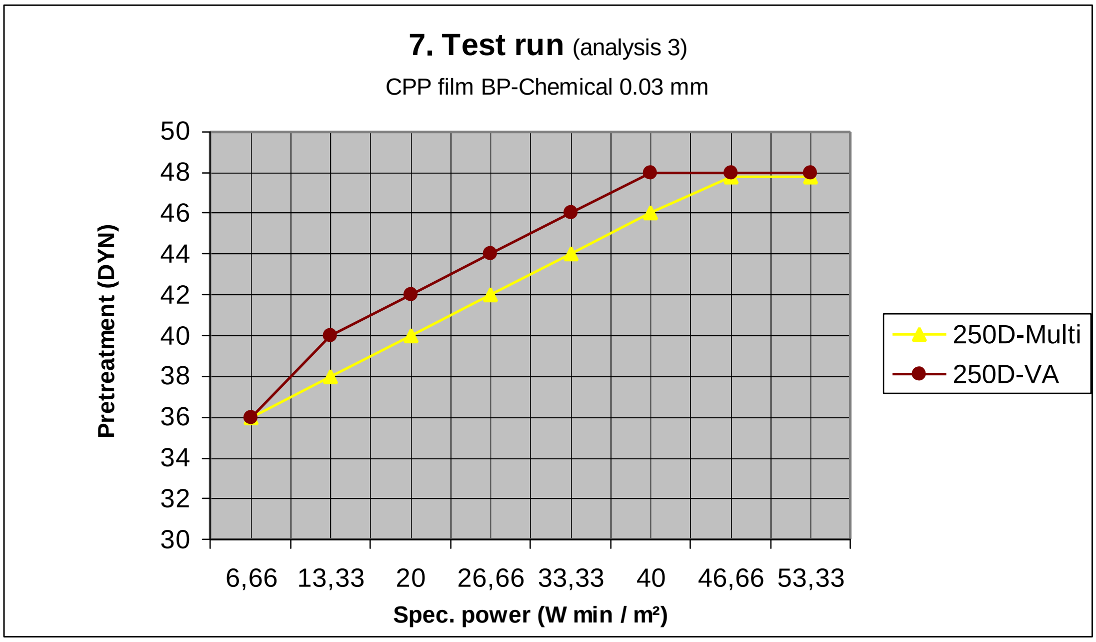
Cause: Local overheating of the film, permanent tear drop-shaped deformations in the film can be seen. Rule of thumb: for typical web speeds using thin films:
approximately 1W/cm max. for conventional multi-electrodes, approximately 4W/cm max. for 12mm stainless steel round electrodes.

New high-grade electrodes

Round stainless-steel electrodes, as compared to aluminum multi-electrodes, offer advantages in the treatment of PP: no reverse side effects at higher treatment power, higher surface energy at the same specific power (efficiency). This can be clearly seen in the following diagrams, where conventional and stainless steel electrodes are directly compared with one another.




7. Test run (analysis 2)
CPP film BP-Chemical 0.03 mm
50
48
46
44
42
40
38
36
34
32
Pretreatment (DYN)
6,66
13,33
20
26,66
33,33
40
46,66
53,33
Spec. power (W min / m²)
200C-Multi
150C-VA

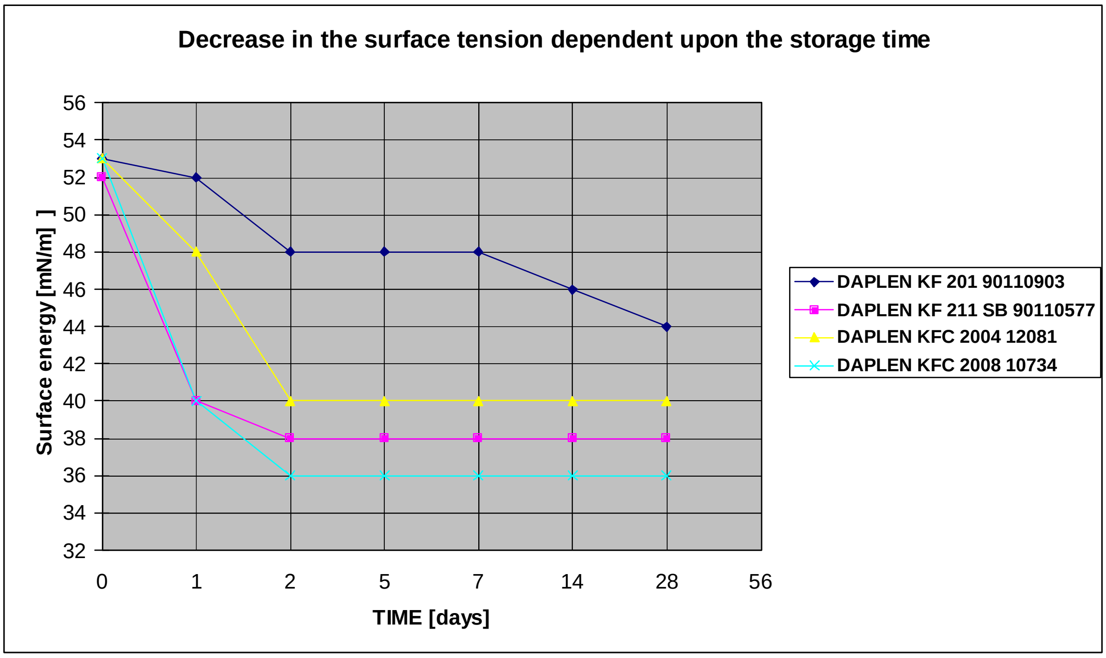

7. Test run (analysis 3)
CPP film BP-Chemical 0.03 mm
50
48
46
44
42
40
38
36
34
32
30
Pretreatment (DYN)
6,66
13,33
20
26,66
33,33
40
46,66
53,33
Spec. power (W min / m²)
250D-Multi
250D-VA

Insufficient long-term stability

Here the corona system is only a little to blame. Basically it is material factors that determine the long-term behavior. This is pointed out in the examination report from Borealis, whose results are graphically compiled below.

However, it should be noted that a distribution of the power which is too widely spread is disadvantageous because the material is only “tickled” at the top-most surface. It’s true that an impressive value, measured directly after the treatment, can be reached, and after a few days almost nothing more can be measured when using critical materials.

In such a case an optimum can be found by removing electrode rails (i.e., by increasing the concentration of the discharge) until the point is reached where barely no reverse side effect takes place at the power needed for the dyne value.



Ozone problems, electrostatic charging

As was previously mentioned, film which is running fast drives an air space along with it. This air contains large amounts of ozone after the corona electrode. A special geometry of the exhaust channels in the corona electrode lets a strong eddy current develop at the film outlet point to enable the removal of this accompanying ozone exhaust.

It is evident that in some polymer systems, the ozone is not completely removed from the film, in spite of the strong extraction force which is sufficient to suck in the film at lower web tensions.

Although the ambient air of the system contains no ozone, succeeding machine parts, especially in the area of the rollers, occasionally display corrosion.

Evidently the ozone clings so strongly to the film that it can not be completely extracted, but is instead, later crushed upon contact with the idle rollers and thereby freed.

The consideration of the electrostatic charges on the web material supplies a theory for this behavior.

It is meanwhile uncontested that the corona discharge brings about strong electrical charges on the PP polymer films. This has not to do with a simple charging which is, for example, known from the charge separation due to friction. Here it is more of a “freezing up” of charges. If the electrode current is monitored with an oscilloscope, a small degree of non-symmetry will be seen, which accounts for a single-poled static charge.

This explains the high linkage force between ozone molecules and the film surface These charged particles are so firmly on or in the film that they can be removed or neutralized only with a great amount of difficulty. This static charge also impairs the ability to wind cast PP foils evenly.

A new type of device (see picture below) is now available; a corona discharge is produced in the interior which simultaneously has air or another gas flowing through it. This gas is stimulated in the discharge gap and is available as a so-called remote plasma at the outlet. Laboratory trials with this Plasma-Jet? or with the Corona-Jet? have shown that the strong charges on the film can hereby be removed. A field trial with a broader device is currently lined up.