Commentary on Shaft Charge versus Hurletron Direct Charge

Shaft charge ESA systems simply attached a wire to the shaft of the impression roll (the shaft must be insulated from ground). The ESA current passes through the wire to the shaft, through the metal shaft to the bearings, through the bearings to the impression roll shell and then to the impression roll rubber surface.

Direct charge systems typically attached the wire to a “contact assembly” that normally feeds the wire to a brush that contacts a ring that, in turn passes the charge to the impression roll shell and then to the impression roll surface.

Both types of systems typically insulate the shaft from the framework though there are some contact assemblies that put the charge into the rubber surface and use the impression roll sleeve to provide the insulating properties.

Bearing Issues

All shaft charge systems pass the current through the bearings. Some use conductive greases to facilitate charge transfer (there is debate whether or not this is necessary). Clearly, more current is passed with conductive greases though that may or may not mean there is a greater ESA effect.

Some customers have suggested there has been some evidence of “burning” of the grease due to the ESA current. Whether or not the current passes through the grease there is no debate that the current is in contact with the grease. It seems reasonable that some “charring” of the grease (it is typically a hydrocarbon based product) might occur.

Others have suggested there is an accelerated wearing (or corroding) of the bearing. This is likely true in that some galvanic corrosion of the bearing surfaces is probably unavoidable. Certainly the high voltages associated with ESA create some ozone which is very active (corrosive) and not good for metals long term.

- Passing the current through the bearing can and typically does result in shorter bearing life.

ESA Energy Levels Issues

The most prevalent shaft charge ESA system is limited in output to about 1,000 Volts. This limitation is necessary to meet the hazardous environment approval requirements of this system. (As an aside this approval also limits the capacitance of the cable from the power supply in such a way that the cable should be longer than a few feet. This can make it difficult to mount the supplies safely. Most installations just ignore the capacitance requirement and put whatever cable is needed.)

The ESA current (which is actually what creates the ESA effect) is determined by the application voltage and the equivalent resistance of the system which, for all practical purposes, is the resistance of the impression roll cover. In other words, Ohm’s Law applys.

$$I = E / R$$

Therefore, given two ESA systems, one able to operate at 2,400 volts and one limited to 1,000 volts and given that they are using the same impression roll. The system limited to 1,000 volts will develop about 40% of the ESA current as the system operating at 2,400 volts. Since the ESA effect is known to be proportional to current (more on that later) the above examples lead to the conclusion that the ESA effect for the 1,000 volt limited system is 40% of the ESA effect for the other system. This conclusion is exactly what happens in practice.

Clearly, the significant reduction in ESA effect described above is not acceptable. In order, to combat this, the systems limited to 1,000 volts typically specify a corresponding lower resistance for the impression roll cover. Again, Ohm's law would seem to indicate this is an effective way to return the currents in the two cases to be equal as shown in the calculations below.

$$I_{esa} = 2{,}400 / 2{,}400{,}000 = 1 \text{ mA}$$

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However, make impression roll surfaces semi-conductive is not very predictable science. Clearly, a given uncertainty in cover resistance has a greater percentage effect at the lower resistance. In fact, the lower of impression roll impedance required in the systems limited to 1,000 volts has lead to less uniform (across the web) results in the use of ESA. The impression rolls tend to develop hot spots where the majority of the current will flow.

- The voltage limitations of shaft charge ESA systems requires lower impedance impression roll covers that typically produce less uniform results.

- The lower impedance covers tend to develop hot spots where most of the current will flow which can lead to premature cover failure.

- The hot spots (most of the current will be flowing here) can present discharge energies that could be problematic. There is too little experience to know how big an issue this will be.

Commentary on Indirect versus Direct Application of the Charge in ESA Systems

Both indirectly and directly charged ESA systems are currently available worldwide. There are some significant performance issues that are important in evaluating the two systems. The purpose of this commentary is to highlight those issues and provide a foundation for accurately communicating the tradeoffs between the two systems.

The effectiveness of ESA is primarily determined by how much the electric field in the impression deflects the ink surface in the Gravure cell. The force on the ink surface is determined by the following equation.

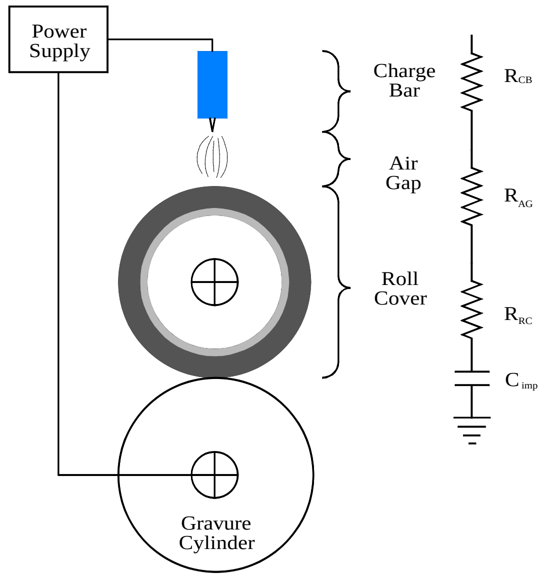
$$F = ½ E^2 / \varepsilon$$

The force (F), and therefore the ink surface deflection, is proportional to the electric field (E) in the impression. The electric field results from current supplied by the ESA power supply.

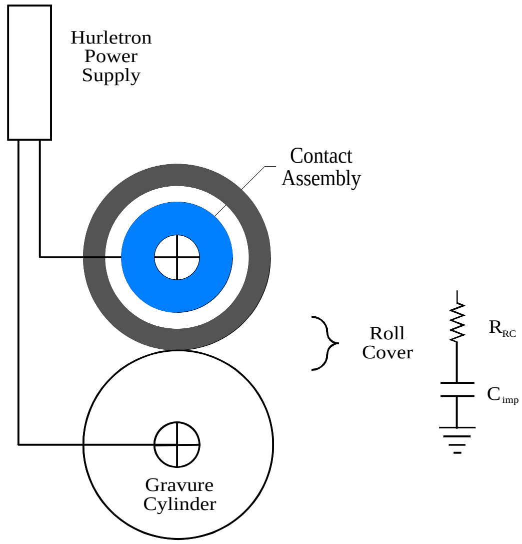
Current Path Issues

The above is true for any ESA system and is completely independent of how the charge is applied. However, the path the current takes getting to the impression plays a significant part in the resulting field that is developed and therefore the effectiveness of ESA.

The current path for an "Indirect Charge" ESA system is as follows.



The current path for a “Direct Charge” ESA system is as follows.



In both diagrams the impression is modeled as a capacitor. The charge bar contains a resistor, the air gap resists the current flow significantly, and the impression roll cover must be somewhat resistive or “semi conductive" to the current flow. Current flowing through the respective “resistors” causes charge to build up in the “capacitor” creating the electric field (E) that does the work.

- The current for indirect charging must pass through the charge bar and ionize the air in the air gap. Both of these resistances dissipate significant energy and directly effect the development of the electric field.

- In direct charge systems the current passes through 1 thickness of the impression roll cover. The current must pass around half the circumference of the impression roll with indirect systems dissipating significantly more energy. As before, any energy lost before the current gets to the impression effects the development of the electric field.

- The current tends to pass along the surface in indirect systems (as opposed to through the semi-conductive layer). Current flow around the surface can become non-uniform as the roll surface becomes polished or otherwise ages due to continuous working of the rubber. Some believe this can lead to localized regions where there is less field.

All of these issues result in the fact that indirect systems tend not to build as strong an electric field as direct systems. Therefore, they rarely perform at the level typical of direct charge systems.

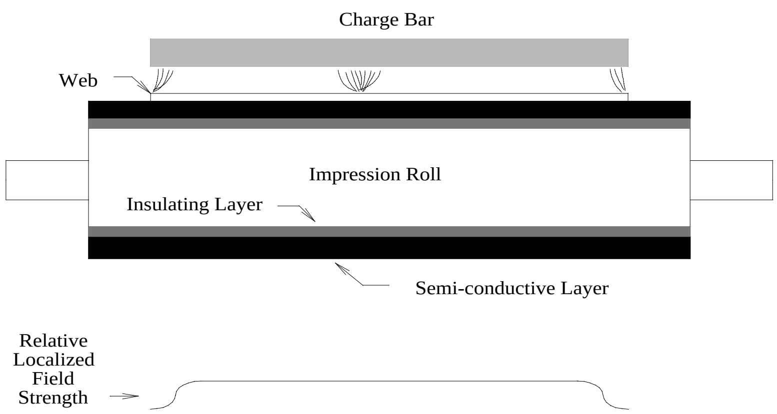
Safety Issues

Indirect systems operate at significantly higher voltages in an attempt to overcome the power dissipation issues stated above. The typical voltage entering the charge bar is in the area of 15 kV to 30 kV. However, as the voltage is increased the resistor in the charge bar must also increase in order to limit the ignition energy available at the pin. (A charge bar is a device for creating a “controlled discharge". Applied to Gravure printing, the bar must limit or “control” the discharge to make sure it is less than the ignition energy of the solvent air mixture.)

- Indirect systems typically do not reach the same electric field strength as direct systems since the resistor in the charge bar must limit the current flow to restrict the discharge to a safe level.

Charge Bar Geometry Issues

The current distribution in an indirect system is illustrated in the following diagram



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At the ends of the bar (the web edges) the current that creates the electric field only flows from the inside. The resultant field strength falls off at the edges as shown in the graph of relative localized field strength.

- Generally, most indirect systems do not perform as well at the web edges.

Cleanliness Issues

The function of a charge bar is to pass current through the air, typically to transfer charge to other objects. Generally, they can not do this preferentially. In other words, everything capable of holding a charge in the vicinity of the charge bar will become charged. Any small liquid droplets as well as any particulate matter, such as paper dust, will end up with an induced charge opposite that of the charge bar. These particles are attracted to the area of the charge bar pins and create a coating on the pins if not cleaned regularly.

- The charge bars in indirect systems must be cleaned regularly to maintain maximum effectiveness. Contact assemblies rarely require cleaning.

Anti-static Issues

All indirect systems use anti-static before and or after the impression. Suppliers of these systems say indirect systems work better because they discharge the web prior to the impression or are safer because they eliminate the charge immediately after the impression. The reality is that they typically ***must*** discharge the web prior to the impression. Remember that indirect systems do not build up a very large electric field in the impression. Any opposing charge on the web as it enters the impression can work against the field created by ESA. This is only significant on indirect systems.

- Indirect systems typically require anti-static prior to the impression due to the limited electric field that they produce. Direct systems do not require anti-static prior to the impression.
- Indirect systems sometimes require anti-static after the impression because the very high voltages used can leave significant charge on the web after printing. Direct charge systems, operating at lower voltage normally leave an insignificant charge on the web and rarely require anti-static after the impression though they can leave a charge on the web in particularly dry conditions.
- With direct systems, anti-static before or after the impression is not typically required though it does no harm and can help under certain conditions.

Anti-static is not added to make indirect systems work better or safer. They are often required to make indirect systems work as well or as safely as direct systems.

Impression Roll Issues

Indirect systems require at least a two-layer impression roll and typically have a 3-layer impression roll. (See earlier diagram) The outer layer is semi-conductive and provides a current path for the ESA current. The middle layer, if it is used, is conductive and evens out the current distribution. The inner layer provides an insulating layer from the impression roll shell or sleeve. Direct systems only require single layer impression rolls but the entire roll must be isolated from ground.

- Two or three layer impression rolls, required for indirect systems, are more expensive and, over time, less reliable due to the second bonding interface between layers.

Web Moisture Issues

Occasionally customers have been told that indirect systems work better than direct systems when sheet moisture is relatively high. As previously noted, for any ESA system the electric field in the impression is what allows ESA to work. Whether direct or indirect, the nature of the field is the same, only the magnitude of the field is different and the magnitude with direct ESA systems is, generally, larger. Moisture does effect the field in that the capacity to build up charge is lower with higher moisture content and therefore the electric field is smaller. However, this is equally true for all ESA systems.

- While anything that makes the web more conductive, such as moisture, does adversely effect ESA, this is equally true for any ESA system. In other words, any system would have the same problem. No system would have the advantage over another.

- If the web is significantly conductive, by virtue of moisture content or web conductivity, all ESA systems have performance issues.