Tam, David
Tutorial #0102

Operating Principles of a Photocopier

This report explains the operating principles of a photocopier and discusses factors which affect the quality of the output. The production of a copy and the removal of that image will be addressed. In the most general sense, photocopiers use the concept of static electricity to produce a copy. The design of the photocopier has improved with time, resulting in cheaper and better machines. Within a few decades these machines have become ubiquitous.

An important part of the photocopier is the image drum (see Figure 1). It consists of a layer of air and a layer of dielectric, known as the photoconductor, both sandwiched between a grounded top and bottom electrode plate (2). In the first stage of the photocopying process the surface of the photoconductor is uniformly charged by a unit called the corotron (2). This surface charge creates an electric field that can be used to attract ink particles (also known as toner). Photoconductors have the unique property of neutralizing any built up charge in regions that are exposed to light. Making use of this fact in the next stage of the process, an image of the intended copy is projected onto the surface of the photoconductor (2). Black areas of the projected image remain dark and retain their charge, whereas white areas of the projected image are lighted and lose their charge. Consequently, the electric field remains only in the dark areas -- where charge is present. Next, black toner powder is distributed across the photoconductor surface where it clings to the remaining charged areas because of the electric fields in those regions (2). Essentially, the remaining particles on the surface form an image of the intended copy. In the final stages of the process the particles are transferred to paper, while preserving their position, and permanently fused to the paper by adding heat (2). The image on the surface is removed indirectly when a subsequent new copy is made. The corotron unit eliminates the old image in the process of uniformly charging the photoconductor surface again.

The corotron is the unit responsible for placing charge on the photoconductor surface (see Figure 2). It is a closed, cylindrical device that deposits charge through slits in its outer shell (6). This device contains two electrodes consisting of the outer shell and a thin wire in the middle of the enclosure. The voltage of the thin wire is increased to a level that causes a discharge (8). When discharge occurs positive charge flows from the wire towards the outer shell. While most of the charge reaches the shell, some manage to pass through the slits and deposit onto the surface of the photoconductor in a thin line formation (6). To cover the entire surface of the photoconductor, the corotron unit is swept across the surface while repeatedly depositing these lines of charge. The net result is a uniformly charged surface.

Figure 1 -- Image Drum (2)

Figure 2 - Corotron (6)

With an understanding of the operating principles, the factors affecting the print quality can now be discussed. The most important factor is the electric field strength which directly affects the ability of the photoconductor to attract ink particles (2). The relative distance of the upper electrode in the image drum to the photoconducting surface largely determines this factor (4). In strict, technical terms it is actually the ratio between the distance from the top electrode to the surface and the bottom electrode to the surface. As the distance decreases the electric field strength increases dramatically which, in turn, greatly increases the attraction of ink particles (4). The thickness and dielectric property of the photoconductor -- also known as the "k"-value -- alters the electric field strength as well (4). A thicker layer and a smaller k-value would likely increase the strength of the field. Similarly, the temperature and humidity of the layer of air in the image drum would affect its respective k-value.

The amount of charge placed on the photoconductor surface is another factor affecting the output quality. A larger amount of charge results in a stronger electric field that attracts more ink particles, producing higher quality outputs. This leads to an examination of the corotron unit, which is responsible for the charge output. The voltage of the wire determines the amount of positive charge released when a discharge occurs. A higher voltage leads to more positive charge emitted. However, the radius of the thin wire and the radius of the outer shell limits the level of voltage that can be placed on the wire (7). The amount of charge emitted by the corotron is also affected by the temperature and humidity of the air inside the unit. Cooler, drier air increases the amount of charge emitted by the device. The number of slits on the corotron shell and their width also determine the amount of charge that is likely to reach the photoconductor surface. Finally, the rate at which the corotron is swept across the surface determines the amount and density of the charge deposited.

The nature of the image is a factor affecting the print quality in older photocopiers while modern, sophisticated ones have addressed this factor (4). Images containing large, continuous areas of black require very strong electric fields to attract an adequate amount of ink particles. Older photocopiers usually produced faint images because this factor was not realized (3). In more expensive, modern photocopiers the electric field is increased by lowering the upper electrode of the image drum (4). However, images composed mainly of thin lines, such as regular text characters, usually produce relatively good quality copies on all machines (4). The electric fields are stronger in these small, thin areas because of a phenomenom known as fringing. The stronger electric fields lead to stronger attraction of the ink particles.

A number of other factors could possibly determine the print quality as well. The size of the ink particles is a factor that could determine the field strength needed for attraction. Finer particles may adhere to the surface despite lower field strengths. Adequate shielding of the photocopier could also be a factor when external electric fields interfere with those on the photoconductor. Finally, the sharpness of the projected image could affect the resolution of the output.

As mentioned in the beginning, the photocopier operates using the principle of static electricity. Since the two major components of this principle are charge and electric fields, it is not surprising that the factors affecting the print quality basically alter either the variable of charge quantity or electric field strength. In summary, the print quality is affected by the ability of the photoconductor to attract ink particles. This ability is directly related to the electric field strength. A stronger electric field results in stronger attraction, leading to higher quality photocopies.

REFERENCES

J.M. Cowley, Fundamentals of Applied Electrostatics, John Wiley, 1986.