KATUN

Straight Talk

On Xerographic Color Technology

Special Edition

How do Digital *Color* Copier/Printers (color DC/Ps) produce full-color copies and prints? In what important ways are they different from traditional analog copiers and black-and-white DC/Ps?

NOTE: *Many concepts and terms used in this document are presented on a more fundamental level in the Katun* Straight Talk on Digital Copier/Printers, *published July 1999. Familiarity with that previously published document will be extremely helpful for the reader in gaining a thorough understanding of this one.*

A digital color copier/printer (hereafter referred to as a "color DC/P") enables the user to scan full-color originals and produce full-process color copies. In addition, most current-generation copiers with such full-process color capabilities can be utilized as printers through a connection to a single computer or network, using a color print "controller" (sometimes referred to as a RIP, for "Raster Imaging Processor").

It is important to specify that, by color DC/Ps, we mean devices that use digital image processing, laser imaging technology, and color toners to produce full-process color copies/prints. This category does not include any analog or digital copiers with more limited color capabilities, such as those able to add a single highlight color to parts of an image or produce single-color images using different-color toners. Nor does it include color inkjet printers, copiers, or copier/printers (such as those readily available from Hewlett-Packard). Such color inkjet devices do not currently offer color image quality comparable to that provided by color DC/Ps, primarily because they do not use laser imaging technology or dry toner, which enable superior image resolution.

In addition to the excellent color image quality they can produce, color DC/Ps can generally be differentiated from other equipment types by their higher purchase prices and operating costs. Color DC/Ps are significantly more expensive to purchase, operate, and service than analog copiers or black-and-white DC/Ps. For numerous reasons explained throughout this document, a typical color DC/P requires more frequent service and parts replacement, and consumes significantly more supplies, than either a typical analog copier or black-and-white DC/P producing the same number of copies/prints. Color-enabled print controllers, which allow personal computers and color DC/Ps to "speak the same language" and produce prints of computer-generated documents, are also relatively expensive, with list prices ranging from approximately US$8,000 to $30,000. The cost of a color print controller is primarily dependent upon its key features and capabilities, such as its processor speed and memory. In contrast, many black-and-white DC/Ps are sold with internal ("embedded") print controllers.

Although the operation of a color DC/P is similar to that of a black-and-white DC/P in some important respects, the imaging (which includes scanning), exposing, developing, transferring, and fusing processes all include critical steps and functions that are unique to color DC/Ps.

This document begins with a look at the current market for color DC/Ps and a brief summary of color DC/P history. A look at basic color reproduction and color blending is next, followed by a step-by-step overview of color DC/P operation, from scanning/imaging through fusing. Finally, some unique aspects of color DC/P toners, photoreceptive drums, and fuser rollers are presented, as well as key profitability considerations for office equipment dealers/distributors that service color DC/Ps.

Today's Color DC/P Market

All the major office equipment OEMs now offer color DC/Ps, either of their own manufacture or on a private label basis. Color DC/P list prices currently range from approximately US$10,000 (for the Panasonic KX-PS8000) to US$130,000 (for the Xerox DocuColor 40). Most color DC/Ps available today are much slower than black-and-white DC/Ps, with speeds ranging from 6 to 9 pages per minute (ppm) when producing color copies/prints. **NOTE:** All color DC/Ps can also produce "black-only" copies/prints at a speed much faster than they produce color copies/prints. A few color DC/P models can produce color copies/prints at a relatively rapid speed –15 to 40 ppm– but list prices for these "high-end" color DC/Ps range from US$70,000 to $130,000.

Compared to average monthly page volumes (AMPVs) produced by analog copiers or black-and-white DC/Ps, color DC/P AMPVs are typically much lower. An AMPV of 10,000 to 15,000 copies/prints would be considered unusually high for a color DC/P; 2,000 to 5,000 copies/prints per month is much more typical. This is due in part to slow operating speeds, as well as the very high costs of OEM supplies and parts, which can prevent end-users from using a color DC/P for anything but their most essential color copying/printing. In fact, color DC/P supplies and parts costs are significantly higher than those for either analog copiers or black-and-white DC/Ps, and actual cost-per-copy/print varies greatly depending upon the average precentage of image coverage on those copies/prints, as well as many other aspects of machine and usage conditions.

The "typical" color DC/P purchaser has a significantly different profile than the "typical" purchaser of analog copiers or even black-and-white DC/Ps. Color DC/Ps are placed most frequently in retail quick print/"print-for- pay" shops, graphic arts departments and agencies, advertising and publishing companies, and the centralized reproduction departments (CRDs) of large- and medium-sized companies. The more specialized end-users in these types of accounts are generally more demanding in terms of both image quality and machine reliability. They are also often more knowledgeable about imaging technology and copy/print production processes than most end-users of black-and-white copiers. Generally speaking, color image quality –and how consistently it can be maintained at a high level– is a more important factor in the color DC/P buying decision, and a greater factor in end-user customer satisfaction with the installed color DC/P, than machine purchase price, rental costs, or supplies costs.

History of Color DC/Ps

The first commercially available copier to produce color images, the Xerox 6500, was introduced in 1973. This analog copier didn't produce "full-process" color images, but instead enabled users to switch developer units so that copies could be produced using an alternative single color toner. Due to the limitations and inefficiency of this type of color copying, this copier and others of similar design were not commercially successful.

In 1978, Canon introduced the world's first full-process analog color copier, the NP Color I. This was the first copier to produce full-process color by combining multiple color toners. Canon also introduced the first digital color copier, the DCC-1, in 1987, which was soon followed to market by Panasonic's first color copier, the FP1. Neither of these early digital color copiers could be connected to a personal computer or network to produce prints.

As of early 2000, there are more than 50 different color DC/P models available from numerous OEMs, with Canon, Xerox, and Ricoh having placed approximately 80% of all the color DC/Ps in the USA (the country accounting for the greatest percentage of worldwide color DC/P placements). Minolta is number four on this list, having placed fewer color DC/Ps in the USA than any of these three leading OEMs, but substantially more than any of the other OEMs.

Recent, very significant growth in the color DC/P market results from many factors, including the "digital transformation" of the business community as a whole—and specifically within the office equipment and printer industries. The proliferation of computers with color monitors in both the business and personal sectors has increased overall demand for color documents (which has also led to dramatic growth in the color inkjet printer market). Lower color DC/P purchase prices, and increased availability of color DC/Ps through resellers (used office equipment brokers), have helped fuel this increasing demand. Improvements in color DC/P connectivity, combined with a dramatic increase in companies utilizing computer networks, has made color copying/printing viable for a wider range of businesses than ever before.

It is worth noting that the various color DC/P models available today not only provide unique features, benefits, and pricing, but that color reproduction itself varies widely between different OEMs, and between different color DC/P models within and between OEM lines. An understanding of the fundamentals of color reproduction is helpful in understanding why such variations exist.

Fundamentals of Color Reproduction

Every day we are exposed to electromagnetic radiation generated by the sun and other energy sources. Radio waves, microwaves, infrared radiation, ultraviolet radiation, X-rays, gamma rays, and visible radiation (light) are all part of the electromagnetic radiation spectrum. Visible light is the only part of this very broad spectrum that can be seen with the naked eye (see Figure 1).

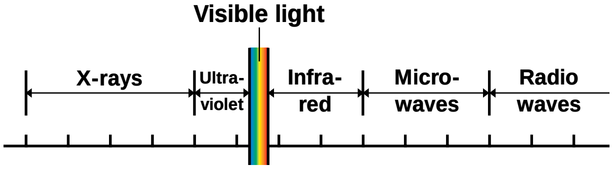


Figure 1. The Electromagnetic Radiation Spectrum.

Electromagnetic radiation is measured in wavelengths, with visible light wavelengths ranging from approximately 400 nanometers (billionths of a meter, abbreviated as "nm") to 700 nm. When waves of visible radiation (or "light rays") reach the human eye, the eye "sees"–and the brain perceives– color. An individual with normal color vision can distinguish between about 7 million different colors. Violet is at the low end of the visible light spectrum (400 nm), while red is at the high end (700 nm). Where a light ray is located along this spectrum of different wavelengths determines what color the eye sees (see Figure 2).

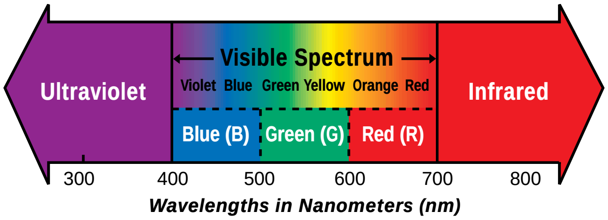


Figure 2. The Visible Light Spectrum.

If color is defined by how it is generated, there are three types: luminous color, transmitted color, and reflected color. All three types play a part in digital color copying/printing. Luminous color is the color emitted by an energy source; for example, the red/orange color of a flame is an example of luminous color (see Figure 3). **The scanning lamp in a color DC/P emits luminous color when exposing/illuminating an original document.**

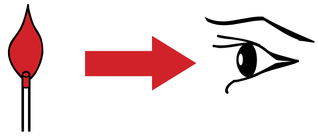


Figure 3. Luminous color is the color emitted by an energy source.

Transmitted color is created when light strikes any transparent or slightly opaque material, and light rays of certain wavelengths pass through while others are absorbed. Shining light through a color slide or filter produces a type of transmitted color. In Figure 4, the filter shown reflects no light, and it absorbs all light except blue, which passes through the filter. We perceive the filter itself to be blue, not because it is reflecting blue light from an energy source above or in front of it, but because it is allowing only blue light (being generated from an energy source behind it) to pass through it. **During the scanning portion of the imaging step in the digital color copying process, the color DC/P uses color filters to separate and transmit color light waves being reflected from an original document.**

IMPORTANT NOTE: When a color DC/P is in its **printing mode, no scanning** of an original document is required because all necessary color image information is contained in the signals processed by the print controller.

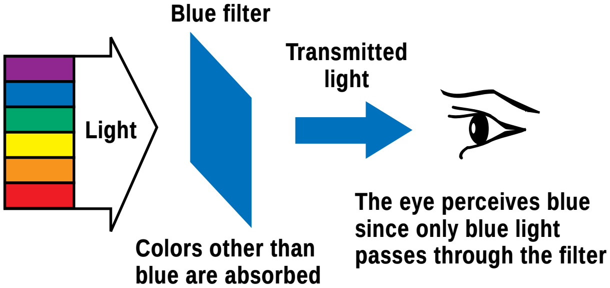


Figure 4. A blue filter transmits only blue light rays.

Reflected color is created when light strikes an object, and that object absorbs some light rays but reflects others. For example, the surface of a ball might absorb all visible light rays except red light rays. These red light rays are reflected, and thus we perceive this ball as red in color (see Figure 5). **Color DC/Ps produce visible color images on copies/prints by applying, blending, and fusing toners that absorb some light rays and reflect others.**

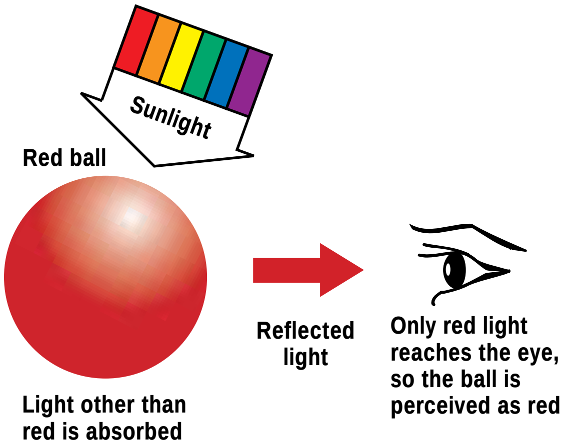


Figure 5. The perceived color of reflected light is determined by the absorption of some light rays, and the reflection of others.

The three primary colors in the visible light spectrum are red, green, and blue. Light rays in the 400 – 500 nm wavelength range are perceived as shades of blue, light rays in the 500 – 600 nm range as shades of green, and light rays in the 600 – 700 nm range as shades of red. Although these primary colors appear to fall within clearly defined parameters, the boundaries between colors are not actually so clear-cut. For example, "between" blue and green exist thousands of shades of blue-green. Between orange and red are thousands of shades of red-orange, and so on. The millions of colors we can see all result from the different wavelengths along the visible light spectrum.

Fundamentals of Color Blending

There are two common methods of color blending: additive and subtractive. Additive color blending (using the primary colors red, green, and blue) is the method that enables computer and television monitors to produce a full range of color. It is called additive color blending because all other colors can be created by adding the three primary colors together in different proportions (see Figure 6). To create black with additive color blending there must be no colors present; an image appears black on your computer monitor because there is no light, and therefore no color, being emitted.

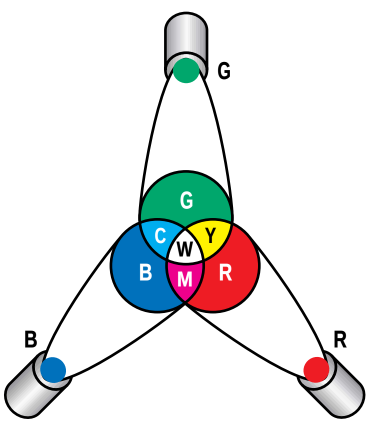


Figure 6. Additive Color Blending.

Color DC/Ps use subtractive blending of color toners to produce a full range of color. The term subtractive is used because the light reflected using this process is less intense than the light emitted by the original source. The three secondary colors in the visible light spectrum **–magenta (M), cyan (C), and yellow (Y)–** are used in subtractive blending. [**NOTE:** Although this color sequence varies by OEM and color DC/P model, MCYK (with K representing black) is the sequence used in explanations and examples throughout this document.] Magenta toner reflects blue and red light, but absorbs ("subtracts") green. Cyan toner reflects blue and green light, but absorbs ("subtracts") red. Yellow toner reflects green and red light, but absorbs ("subtracts") blue (see Figure 7).

Light / Toner Color	Red	Green	Blue
Magenta	Reflects	Absorbs	Reflects
Cyan	Absorbs	Reflects	Reflects
Yellow	Reflects	Reflects	Absorbs

Figure 7. Subtractive Color Blending.

When any two or more of the secondary colors are blended together, the range of wavelengths being absorbed expands. For example, blending yellow toner (which absorbs blue light rays) and magenta toner (which absorbs green light rays) allows only red light to be reflected. Consequently, **melting yellow and magenta toner together and fusing them into the surface of a sheet of paper produces a red image.** Melting yellow and cyan toners together results in the absorption of blue and red light, and the reflection of green light. Melting magenta and cyan toners together produces a blue image, and so on. Because the substrate (paper) is white, in order to produce a black image the toner on the paper must absorb all colors and reflect none. By melting together all three secondary-color toners, all blue, green, and red light rays are absorbed. The resulting image appears black (see Figure 8). **NOTE:** While black is often referred to as a color, technically it is the absence of color. Our eyes "see" black when the area or object we are viewing reflects no colored light waves.

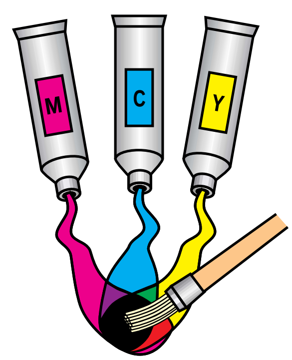


Figure 8. Blending all three subtractive colors results in "process" or "composite" black.

Unlike some early-generation color copiers that used this "process" (or "composite") combination of all three secondary-color toners to produce black images on copies, **virtually all current-generation color DC/Ps use separate, high-density black toner** (and developer) in addition to individual magenta, cyan, and yellow toners/developers. This enables bolder, more "crisp" black images on copies/prints—a highly desirable image quality characteristic for many color DC/P end-users. **NOTE:** In many color DC/Ps, a layer of black toner is also used to create shades of many colors other than black itself.

At this point, it is important to understand that a **"typical" color DC/P must perform separate, distinct imaging, developing, and transferring steps for each of its four toners. The culmination of all these steps is that the different color (including black) toners are physically "stacked" in separate layers on the paper, ready to be fused in a single pass through the fuser station to produce the final full-color image on a copy/print** (see Figure 9).

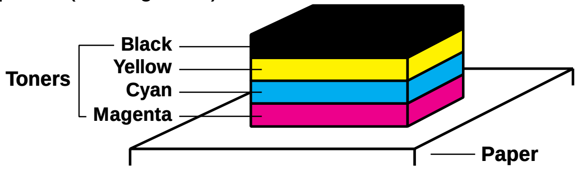


Figure 9. In a color DC/P, toners are "stacked," in separate layers, on the paper in preparation for single-pass fusing of the image.

IMPORTANT NOTE: As previously stated, when a color DC/P is in its **printing mode, no scanning** of an original document is required because all necessary color image information is contained in the signals processed by the print controller. However, **in the printing mode, separate, individual imaging (excluding scanning and color separation), developing, and transferring steps for each color toner are still required –just as in the color DC/P's copier mode– to produce a toner "stack" on the page, in preparation for single-pass fusing.**

Scanning (and Color Separation)– Copying Mode

In order for a color DC/P to produce a color copy of an original color document, extensive information about the original document's colors and color density must be extracted through scanning and color separation. To extract color information from the original document, the image must be separated into the three primary colors: blue, green, and red. This separated color information is then converted into digital signals for additional color processing. **NOTE:** Most current-generation color DC/Ps perform an **initial scan** primarily to detect the size and location of the original document and determine whether a black-and-white copy of a black-and-white original should be produced. If a color copy is required, **four more separate scans** of the original document are then performed to extract additional color information (see Figure 10). This information is used in exposing the OPC drum surface, sequentially creating **four separate latent images, each followed by its own toner development cycle,** for each of the **four different toners** (magenta, cyan, yellow, and black) used in the system. (**Note:** The example of a color DC/P with a single OPC drum is used throughout this discussion.)

Scanning Sequence	Purpose
#1 (initial)	Determines size and location of original document, and whether copying requires color toner(s) or only black toner
#2	**M** – Determines where (and how much) **MAGENTA** toner must be developed (on the OPC drum surface)
#3	**C** – Determines where (and how much) **CYAN** toner must be developed
#4	**Y** – Determines where (and how much) **YELLOW** toner must be developed
#5	**K** – Determines where (and how much) **BLACK** toner must be developed

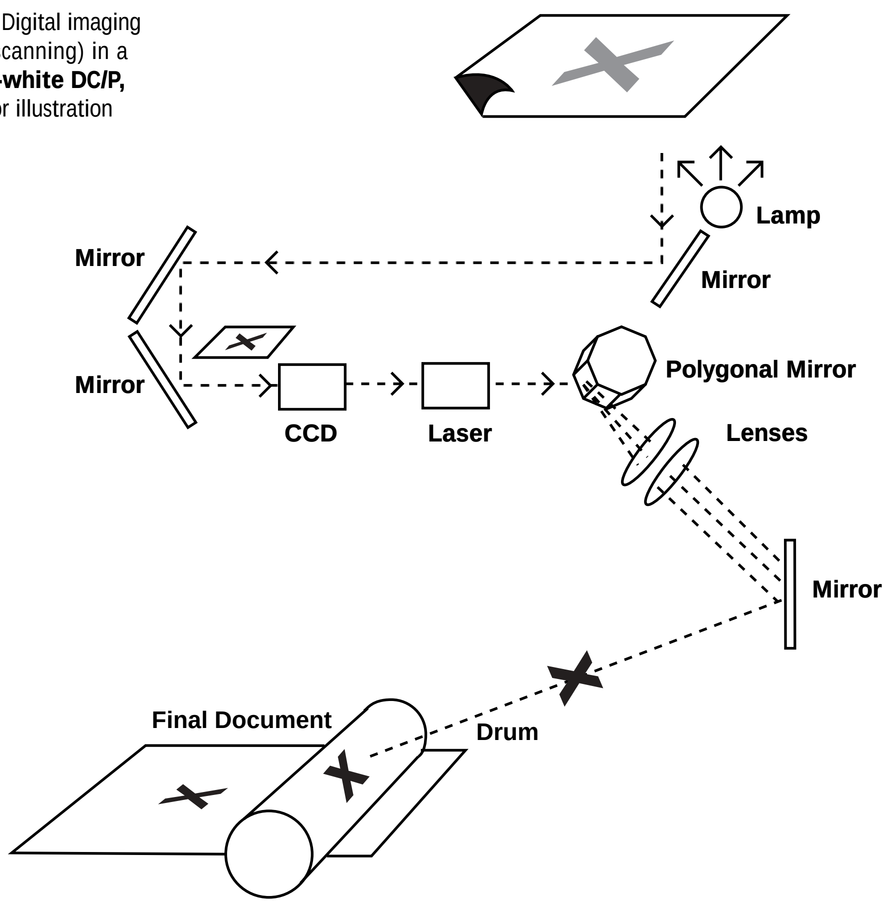
Figure 10. "Initial/MAGENTA/CYAN/YELLOW/BLACK" is the color scanning sequence used in many Canon color DC/Ps, and in the "typical" system discussed in this document. The exposing, developing, and transferring steps in a color DC/P all follow the same **color** sequence as scanning, culminating in a multi-layer toner stack on the paper, ready for single-pass fusing.

A color DC/P uses blue, green, and red filters to extract information about the presence and density of these primary colors from the original color document. Light passed through color filters produces transmitted color—each color filter is made of a slightly opaque material that allows only a certain range of wavelengths of light (corresponding to a certain color range) to pass through it. For example, a blue filter allows only blue light rays to pass through it, but not green or red. Similarly, the red light rays reflected off the image of a red ball will pass through only the red filter. It is through this process of separating and extracting the primary colors from an original color image that the color DC/P can determine which color toners, in what amounts, it must ultimately fuse into the top surface of the paper to produce a color copy.

Imaging–Copying Mode

When a black-and-white DC/P scans an original document in order to produce a copy, it reflects an image from the original document to a "charge coupled device" (CCD). The CCD, which contains thousands of photosensitive cells in a single row, receives the stream of reflected light one line (one row of dots) at a time, and rapidly converts it into an analog data signal. That analog signal is then sent to a multifunctional circuit board for conversion into a digital data signal. The circuit board transmits this stream of digital information (as a series of "1s and 0s") to a semiconductor laser which switches on and off in response to the signal, transmitting a pulsing beam of light onto the surface of the OPC drum (see Figure 11).

Figure 11. Digital imaging (including scanning) in a **black-and-white DC/P,** simplified for illustration purposes.



In its copying mode, a color DC/P uses this same basic imaging process. However, the color DC/P must develop up to four separate latent images (corresponding to magenta, cyan, yellow, and black toner) on the OPC drum surface to ultimately produce one full-color toner image on paper. Thus **the CCDs and associated circuitry used in color DC/Ps are, by necessity, much more complex than those used in black-and-white DC/Ps.**

In a color DC/P, the CCD consists of three rows of photosensitive cells, with a blue, green, and red filter each covering one row (see Figure 12). As light is reflected off an original document during scanning, only light rays the same color as a photosensitive cell's filter pass through the CCD for conversion into a digital signal. For example, when scanning an original document with a blue image only, blue light rays would pass through to the row of photosensitive cells covered by the blue filter. No light rays would pass through to cells in the rows covered by the green or red filters. **NOTE:** When a color original is scanned, any "pure" (high-density) black image absorbs light and reflects virtually no color light rays. The DC/P will recognize this lack of any light passing through the CCD cells as the existence of a black image, and will develop a corresponding black image using all four color toners. A gray (less dense black) image reflects some blue, green, and red light waves, in equal amounts. These rays will pass through their respective filters, resulting in the development of a gray image using magenta, cyan, and yellow toners.

NOTE ON DESIGN VARIATIONS IN HIGHER-SPEED DC/Ps: Some higher-speed color DC/Ps (such as the 31 color ppm Canon CLC-1000, 24 color ppm Canon CLC-2400, and 40 color ppm Xerox DocuColor 40) are equipped with sufficient memory to collect and store all necessary color information via a single scan. Such systems also utilize four OPC drums –one for each toner/developer unit– rather than a single drum, to increase speed and operating efficiency.

Exposing–Copying and Printing Modes

The exposing process in a typical black-and-white DC/P includes the transmission of image data from the circuit board (in the form of a digital signal) to a semiconductor laser, which switches on and off in response to this digital signal. At every point where the pulsing beam of light strikes the OPC drum surface, it "erases" the existing negative charge from a tiny dot on the drum surface, effectively creating a "less negative" or "neutrally-charged" latent image on the drum that corresponds with the image on the original document.

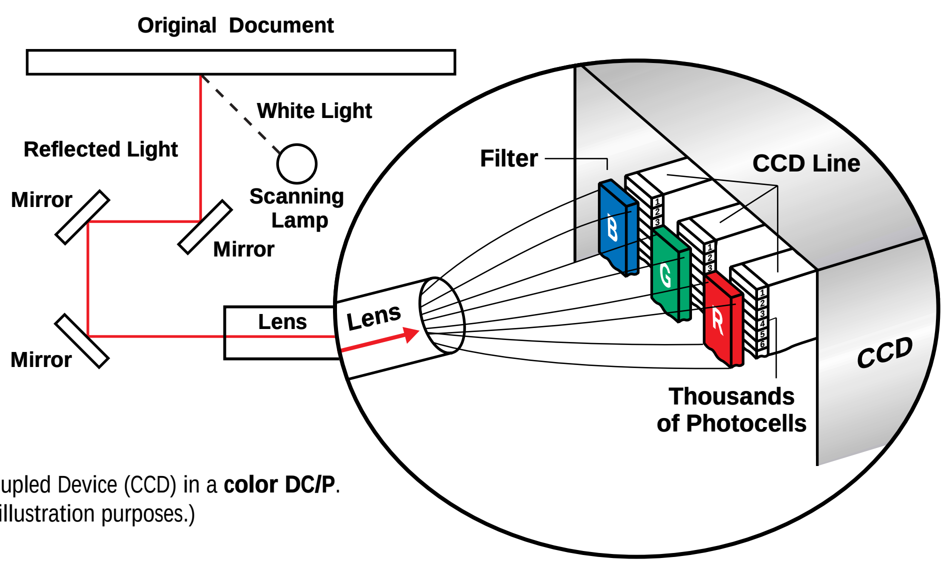


Figure 12. Charge Coupled Device (CCD) in a **color DC/P**.
(Greatly simplified for illustration purposes.)

A color DC/P creates a latent image on the drum surface in the same manner as a black-and-white DC/P. However, it does so up to four separate times per color copy/print, in a predetermined sequence, in order **to process the signals from up to four individual scans.** Consequently, **the OPC drum in a typical color DC/P must complete four drum rotations, receiving a different latent image each time, to ultimately produce a single, full-process color copy.**

Developing–Copying and Printing Modes

Whereas a black-and-white DC/P employs a single developing unit to apply black toner (only) to the OPC drum in a single process step, a typical color DC/P has **four separate developing units** and must sequentially develop four separate toner images on the surface of the single OPC drum. To accomplish this, most color DC/Ps use one of the following: a fixed-position, rotary, or sliding development mechanism (see Figures 13a-c). A few high-speed color DC/Ps incorporate a four-drum system that utilizes four OPC drums (one for each color toner), each with its own developing unit (see Figure 13d).

Figure 13a. Fixed-Position Mechanism

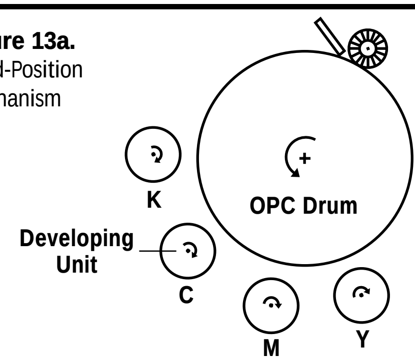


Figure 13b. Rotary Mechanism

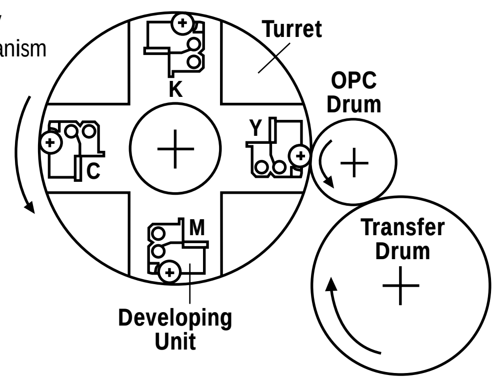


Figure 13c. Sliding Mechanism

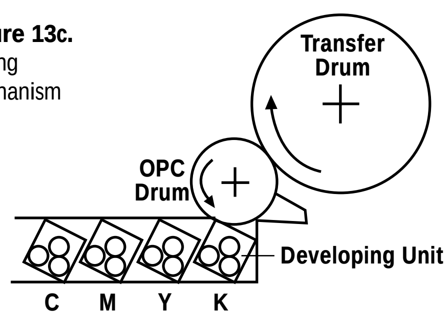
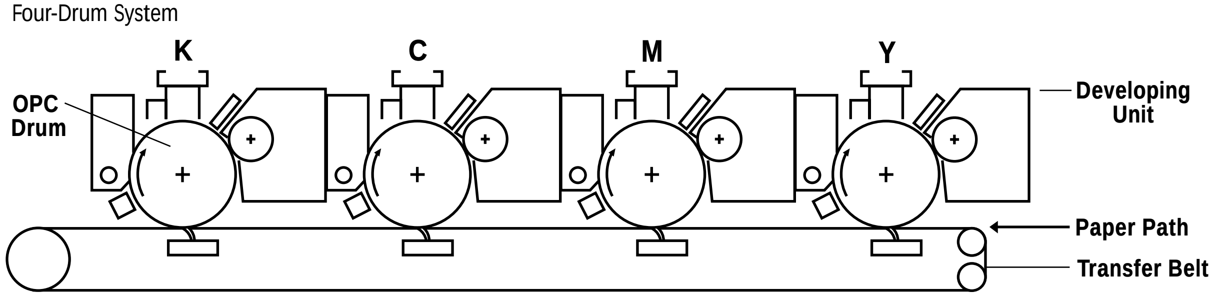


Figure 13. Various types of color DC/P development mechanisms, using different methods of sequentially applying four different toners to the OPC drum from four separate developing units –or, in the case of Figure 13d, applying the four different toners to four individual OPC drums– in preparation for single-pass fusing of the color image.

Figure 13d. Four-Drum System



In a color DC/P using a fixed-position development mechanism, the individual developing units for each of the four colors are configured around the OPC drum. In the appropriate sequence, each developing unit is moved into close proximity to the drum surface to apply toner. Because this type of development mechanism requires a separate contact point for each developing unit, it typically necessitates the use of a larger-diameter OPC drum. (For example, the current-production Canon CLC-900 incorporates a fixed-position development mechanism and a single 180mm-diameter OPC drum.)

In a rotary development mechanism, the four developing units are located on the perimeter of a revolving device often called a "turret." For application of each color toner, this turret performs a partial rotation, placing the appropriate developing unit in close proximity to the OPC drum surface to apply toner. (This type of development mechanism is utilized in the older Canon CLC-500, among other color DC/P models.)

In a sliding development mechanism (such as that utilized in the older Canon CLC-300), the four developing units are located on a device that slides horizontally, bringing each of the developing units, in proper sequence, in close proximity to the drum surface to apply toner. **NOTE:** Because a single contact point is used for all four developing units, a color DC/P using either a sliding or rotary development mechanism can utilize a smaller-diameter OPC drum than those using a fixed-position development mechanism. This enables more compact color DC/P designs.

In a four-drum system, each drum develops a separate single color (MCYK) image simultaneously, and each has its own developing unit. Because this system enables simultaneous development of the four colors followed by rapid transfer of the image from the drums to the copy paper, machines utilizing this system are capable of output speeds signifiantly higher than a color DC/P using one of the previously described development mechanisms (15 to 40 ppm in color mode vs. 6 to 9 ppm).

NOTE: Regardless of the type of development mechanism used in a color DC/P with a single OPC drum, **drum cleaning must be performed after each of the four toners is developed on the OPC drum surface to maintain the integrity of each individual developed color image.** After each development cycle, any remaining toner is removed by the drum cleaning assembly, and a uniform negative electrical charge is once again applied to the OPC drum by the charging assembly (typically utilizing a corona wire).

Transferring–Copying and Printing Modes

The most common method of transferring toner from the OPC drum surface to paper in today's color DC/Ps is the use of a **transfer drum**—essentially a large hollow tube with a semi-transparent plastic surface. (**NOTE:** In some higher-speed color DC/Ps, a transfer belt is used instead.) As the first of four toner images is being developed on the OPC drum, copy paper is fed from the paper tray or cassette to the transfer drum. An electrostatic charge attracts and holds the copy paper firmly on the transfer drum throughout the toner transferring process.

As the transfer drum and OPC drum rotate in opposing directions (see Figure 14), the paper comes in contact with the developed toner image on the OPC drum. To attract the negative-charge toner from the OPC drum surface to the copy paper, a positive charge is applied to the back of the paper using a transfer brush or corona wire located just beneath the surface of the transfer drum. **To prepare a single full-process color copy/print for fusing, this entire transferring process must be performed once for each of the three color toners, plus black toner.** Thus the transfer drum, like the OPC drum, can be required to complete up to four rotations per color copy/print.

The copy paper remains on the transfer drum for the completion of these four complete toner transfer cycles, until **all four separate toner layers are appropriately and sequentially stacked to form an unfused color image on the paper. The paper is then transported on to the fuser station.**

Transferring is the last step in the color DC/P xerographic process to be performed in multiple cycles for each color copy/print. As previously stated, color DC/P **fusing is performed in a single pass.** However, the complexity and challenges of toner fusing in a color DC/P are also very unique, in comparison to toner fusing in an analog copier or black-and-white DC/P. Rather than melting and pressing a single layer of black toner into the paper fibers on the top surface of the paper, **a color DC/P must be able to properly and precisely melt, blend, and press a four-layer toner "stack" into these paper fibers.**

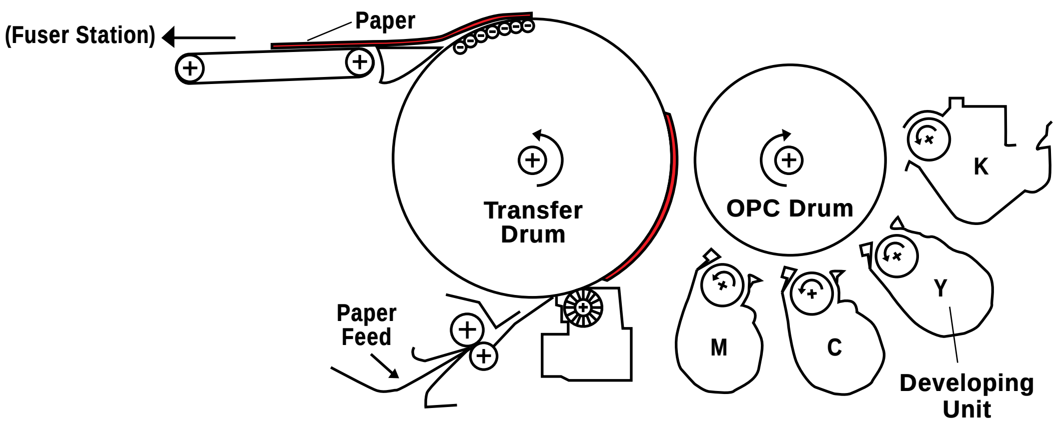


Figure 14. During transferring of toner from the OPC drum surface to copy paper, the copy paper is held firmly to a "transfer drum," by an electrostatic charge.

Review of the Color Xerographic Copying Process, through use of a Simple Example

Before thoroughly examining the single-pass fusing process in our "typical" color DC/P (with its single OPC drum, "MCYK" development sequence, and transfer drum), it may be helpful to briefly recap the prior steps in the color xerographic copying process, using a simple example. For these purposes, consider an original document containing one red circle, one cyan square, and one black rectangle (see Figure 15). How does the color DC/P create unfused color toner "stacks," properly positioned on the copy paper to produce an accurate full-color copy once the toners have been melted, blended together, and fused into the surface of the paper?

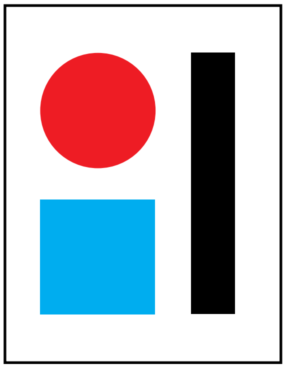


Figure 15. Simple color document example for explanatory purposes.

1. Initial scan

When activated, the color DC/P performs its initial scan of the original document, using an exposure lamp for illumination. With the information gathered during this scan, the color DC/P determines that a full-color (rather than black-only), letter-sized copy is required. The toner development cycles can then begin. Keep in mind that, although explained in a linear sequence here, portions of each cycle occur simultaneously with portions of the subsequent cycle, in order to achieve acceptable color copying/printing speed. When toner development begins, for example, a uniform negative charge has already been applied to the OPC drum surface.

2. MAGENTA toner development cycle

A second scan determines where MAGENTA toner must be developed. Because the black rectangle reflects little or no light (depending on its density), no light passes through any of the CCD's filters. The DC/Ps processing system recognizes this absence of light being reflected from the black rectangle as black. Since a finished black image requires development of all four color toners (MCYK), a digital signal is sent to the laser. Green and blue light rays from the CYAN square pass through their respective CCD filters, but are not sent to the laser. However –because MAGENTA toner, plus YELLOW toner– is required to produce a red image, the red light rays reflected from the red circle pass through the red filter to the CCD. This information is converted to a digital signal and sent to the laser. The laser discharges the points on the uniformly charged OPC drum surface that precisely correspond to all points within the original image that reflect either red light or “no light” (the black rectangle). As the drum rotates, negative-charge MAGENTA toner is applied to the drum surface by the development mechanism, and is attracted only to those areas that have been rendered “less negative” by the laser beam. The OPC drum now has on it both a circle and a rectangle of MAGENTA-colored toner, held in place electrostatically.

This MAGENTA toner is then transferred from the OPC drum surface to the copy paper, which is in place on the rotating transfer drum. The copy paper adhering to the transfer drum comes into contact with the rotating OPC drum, and the negative-charge MAGENTA toner is attracted to the copy paper due to the positive charge applied to the paper from within the transfer drum. This MAGENTA toner forms **the first layer in the images of the circle and the rectangle** on the paper, (see Figure 16a on page 13). Then, any toner remaining on the OPC drum surface is removed by the drum cleaning assembly, and a uniform negative electrical charge is once again applied to the OPC drum by the charging assembly in preparation for the next color toner development cycle.

3. CYAN toner development cycle

During the next scan, the color DC/P uses a similar process to determine where CYAN toner must be developed. The blue and green light rays reflected off the CYAN square pass through the blue and green filters to the CCD and are converted to digital signals by the circuit board. The CCD determines the intensity of these light rays, and the circuit board sends to the laser a digital signal with a precise CYAN value. As during the MAGENTA development cycle, the black rectangle reflects no light. The processing system recognizes that this image is black, and generates a corresponding digital signal which is sent to the laser.

The laser discharges the points on the OPC drum surface that precisely correspond to the points within the original image that reflect blue and green light, or that reflect no light (i.e., the black rectangle). This creates a “less negative” latent image of a square and a rectangle on the OPC drum. In contrast, the red light rays reflected off the red circle pass through only the red filter, so the corresponding areas of the drum surface remain fully charged. No signal is sent to the laser because the color DC/P is, at this point, determining necessary CYAN toner development only.

"MCYK" Development Sequence

These five figures illustrate the four stages of image development, plus the final fused image, when making color copies of a document like the one shown in Figure 15. These illustrations are replicates of the actual development/transfer stages. For Figures 16a through 16d, sample prints were removed from a color DC/P after each of the developed images were transferred to the copy paper, but prior to fusing. Figure 16e represents the final, fused image.

Figure 16a.
Magenta Toner Development/ Transferred Image

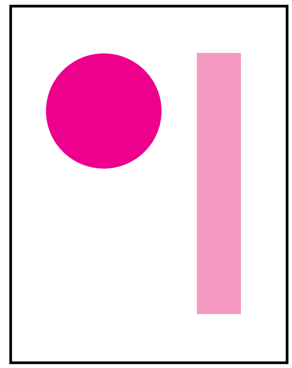


Figure 16b.
Cyan Toner Development/ Transferred Image

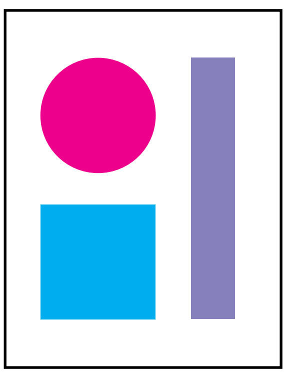


Figure 16c.
Yellow Toner Development/ Transferred Image

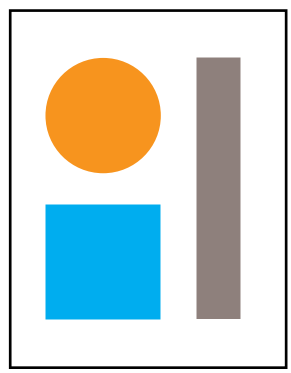


Figure 16d.
Black Toner Development/ Transferred Image

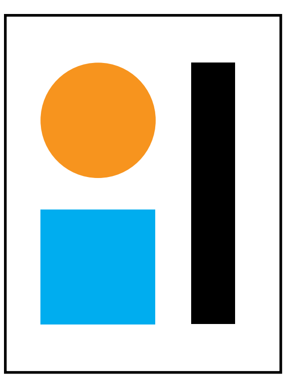
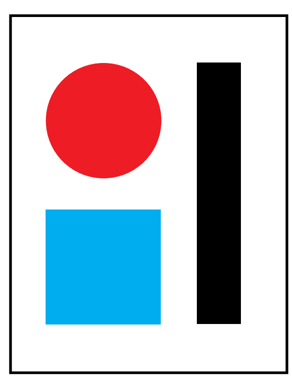


Figure 16e.
Final, Fused Image



As with MAGENTA toner in the previous cycle, CYAN toner is applied to the OPC drum surface and then transferred to the copy paper. As seen in Figure 16b on page 13, this layer of CYAN toner forms the **image of the square** on the paper, and a layer of CYAN toner that corresponds to the black rectangle is transferred on top of the layer of MAGENTA toner already developed. Notice how the image of the "black rectangle," which at this stage has both MAGENTA and CYAN toner on it, appears purple. OPC drum cleaning and drum charging are repeated.

4. YELLOW toner development cycle

In order to accurately copy the original document's red circle, the color DC/P must add a layer of YELLOW toner to the unfused circle of MAGENTA toner already on the copy paper. During the scan for YELLOW toner development, red light rays pass through the red filter again and the laser discharges the drum in exactly the same area as it did before when preparing to develop MAGENTA toner. As with the first two development cycles, a signal representing the black rectangle is also sent to the laser. YELLOW toner is applied to the drum and transferred to the copy paper, directly on top of both the previously applied MAGENTA toner circle and the rectangle which now consists of a layer of CYAN toner on top of a layer of MAGENTA toner. This YELLOW toner forms **the second layer in the circle** on the paper, and **the third layer in the rectangle** on the paper (see Figure 16c on page 13). Notice that the image of the black rectangle now appears gray, rather than a dense black. This is what composite black looks like without the addition of black toner. To begin the next cycle, OPC drum cleaning and drum charging are repeated once again.

5. BLACK toner development cycle

Only **the black rectangle** on our original document needs further development, to give the black image its required density. A fifth cycle of scanning through drum cleaning and re-charging, similar to the complete color toner development cycles described above, is necessary for the placement of the color DC/P's high-density black toner on the copy paper for fusing. The black toner is placed directly on top of the previously developed layers of MAGENTA, CYAN, and YELLOW toners (see Figure 16d on page 13). The unfused image of the rectangle on the paper now consists of four layers of toner. Notice that the red circle is not red at this stage, but a shade of orange. That's because the magenta and yellow toners have not been melted and blended yet.

In the color DC/P fuser station, the MAGENTA toner layer must be melted and blended with the YELLOW toner layer to create the red circle. The resulting fused toner circle will absorb blue and green light, but reflect red light, producing on the copy paper an image of a red circle that very closely approximates the red circle on the original document. The MAGENTA, CYAN, YELLOW, and BLACK toner layers will fuse to create the black rectangle. The CYAN toner will fuse "as is" without any blending, creating an accurate image of the CYAN square. (See Figure 16e on page 13.)

This very simple example breaks down the "typical" color xerographic process for better understanding, but does not truly account for real-world color copying/printing. The many shades of many colors that must be reproduced in copying/printing a typical photograph, for example, require **toner stacking in four layers corresponding to all four toners used in the system,** rather than just one or two layers. This is a major factor in the complexity of, and precision required for, successful color DC/P toner fusing, which is in turn a critical factor in the color image quality produced by any color DC/P.

Fusing–Copying and Printing Modes

Along with the presence of multiple developing units to complete multiple toner development cycles, perhaps the most significant differences in color DC/P technology from black-and-white DC/P technology are in the fusing process. Although the elements applied to accomplish toner fusing –heat, pressure, and time– are the same, there are critical, major differences in the use of each of these elements in a color system vs. a black-and-white system. **Several technological factors make fusing in a color DC/P extremely demanding and complex.**

Successful toner fusing in a color DC/P requires melting together and physically blending a stack of (up to four) multiple, separate toner layers. Generally speaking, this toner stack is at least four times the height (thickness) of a single layer of black toner. This creates much more demanding heat transfer/distribution requirements than those in a typical analog copier or black-and-white DC/P, where only a single layer of black toner must be fused into the top surface of the paper (see Figures 17a-b).

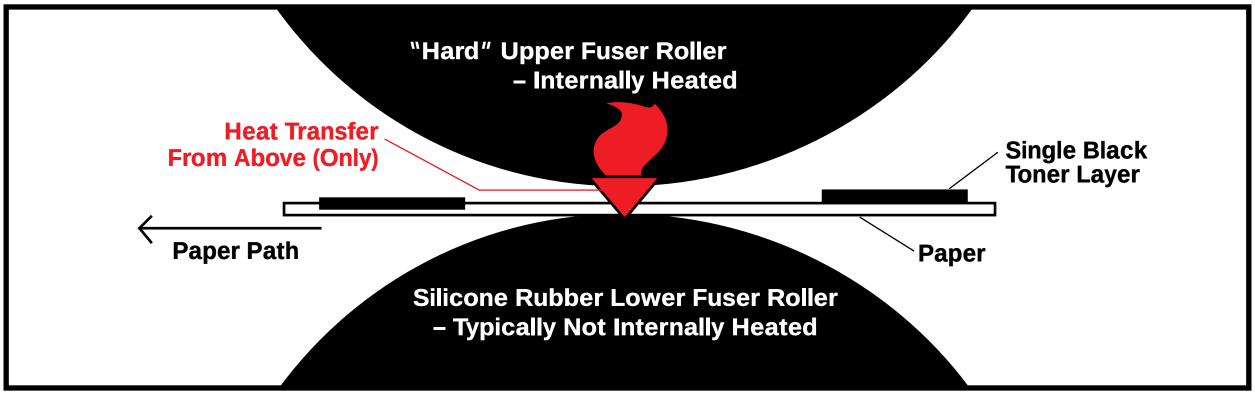


Figure 17a. Heat transfer from above only. This is acceptable in some analog copiers or black-and-white DC/Ps because the thickness of the toner is far less than a typical toner stack in a color DC/P. (**NOTE:** Illustration not drawn to scale. Distance between upper and lower rollers is inserted for illustration purposes only; upper and lower rollers are actually in contact.)

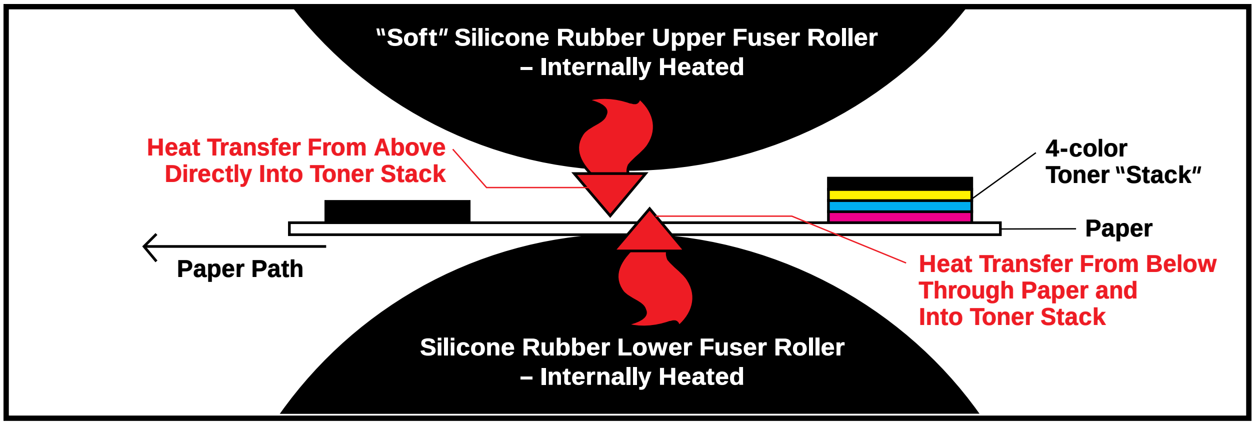


Figure 17b. Simultaneous, bi-directional fusing is essential in a color DC/P. Both upper and lower fuser rollers are heated from within, and transfer/distribution of heat is accomplished **both from above and below the toner stack**. Bi-directional fusing is a neccessity in a color DC/P because the toner stack is thicker than the single layer of toner being fused in an analog copier or black-and-white DC/P. (**NOTE:** Illustration not drawn to scale. Distance between upper and lower rollers is inserted for illustration purposes only; upper and lower rollers are actually in contact.)

Simultaneous, bi-directional fusing is essential for this purpose: **all color DC/Ps incorporate upper and lower fuser rollers that are both heated from within by halogen lamps, in order to completely melt all the layers of toner for proper physical blending.** In a color DC/P, heat is transferred both: (1) into the toner stack from above, and (2) through the paper and into the toner stack from below.

This simultaneous, bi-directional transfer/distribution of heat must be tightly controlled and consistently maintained to produce acceptable color toner images. If, for example, the top two layers of toner in the stack were melted into a liquid state before the bottom two layers, effective toner blending could not occur, and unacceptable color image quality would result. **NOTE:** The precise relationship between heat applied from above and below varies by color DC/P OEM and by specific model. In fact, the wattage of the heater lamps within the upper and lower rollers may be the same, slightly different, or considerably different, depending on the specific color DC/P model.

The fusing temperature operating "window" in a typical black-and-white copier ranges from 180° to 200°C. In contrast, the effective fusing temperature for a color DC/P is generally between 150° and 170°C (although some higher-speed color DC/Ps perform fusing at a higher temperature). This less intense application of heat energy in the color DC/P fuser station makes consistent, uniform transfer/distribution of that heat energy extremely important to effective fusing.

In addition to being uniformly melted (liquefied) and thoroughly blended via precisely controlled, uniform heat transfer, **the color toner stack must be compacted, or "flattened" and "smoothed," through the application of pressure.** In other words, the height of the toner stack must be significantly reduced, and the "rough" appearance of the unfused toner stack eliminated, in order to produce an acceptable color image on the final copy/print. With current color toner and fuser roller materials and technologies, **this can be accomplished only with relatively "soft" silicone rubber fuser rollers**—not with the harder, more abrasion-resistant fluoropolymer-coated fuser rollers commonly used in analog copiers and black-and-white DC/Ps.

The greater flexibility and compliance of soft silicone rubber fuser rollers is essential to preventing the "toner shear" problems that would occur if a color toner stack were impacted by the much harder, less yielding surfaces of fluoropolymer-coated fuser rollers (see Figures18a-b). "Toner shear," in this case, refers to a too-forceful compression of the color toner stack, forcing the upper toner layers in the stack outward rather than directly down into the lower toner layers in the stack. This would result in inadequate color toner blending and serious color image quality problems. In contrast, the more flexible, compliant surfaces of silicone rubber fuser rollers minimize the movement of toner particles and layers throughout the **simultaneous, bi-directional application of pressure (and heat),** enabling proper blending of all layers of color toner in the stack as they are pressed into the top surface of the paper. Consistently maintaining the proper nip width –i.e., the precise area where the two fuser rollers are in contact– is also essential, and the ability of soft silicone rubber fuser rollers to rapidly "snap back" (without taking a compression set) after fusing each successive copy/print, is very important in this respect. Additionally, the use of silicone rubber fuser rollers enables color DC/Ps to produce copies/prints on media that are very susceptible to toner shear, primarily transparencies and iron-on decals (see page 21 for more information regarding alternative media used in color DC/Ps).

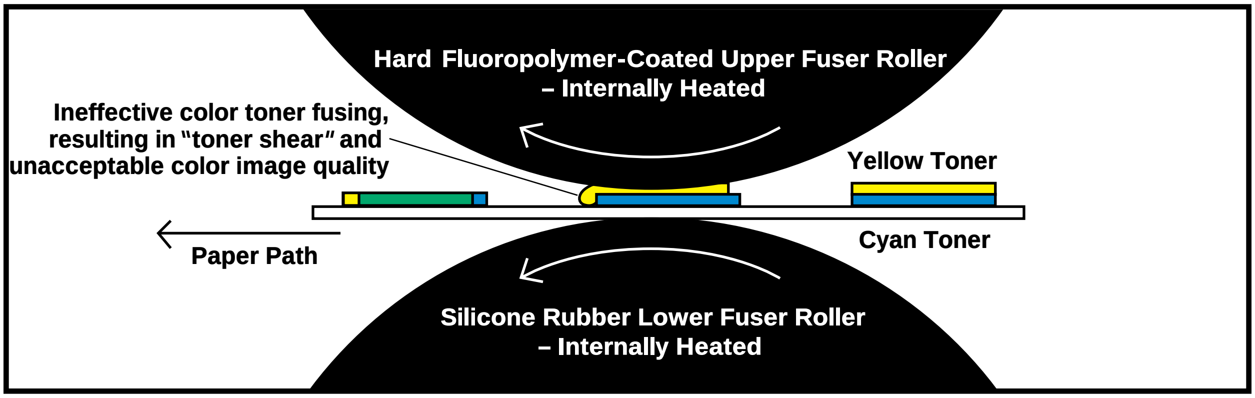


Figure 18a. Attempting to fuse multiple layers of color toner with a hard fluoropolymer-coated upper fuser roller would typically cause "toner shear," resulting in inadequate toner blending and poor image quality. (**NOTE:** Illustration not drawn to scale. Distance between upper and lower rollers is inserted for illustration purposes only; upper and lower rollers are actually in contact.)

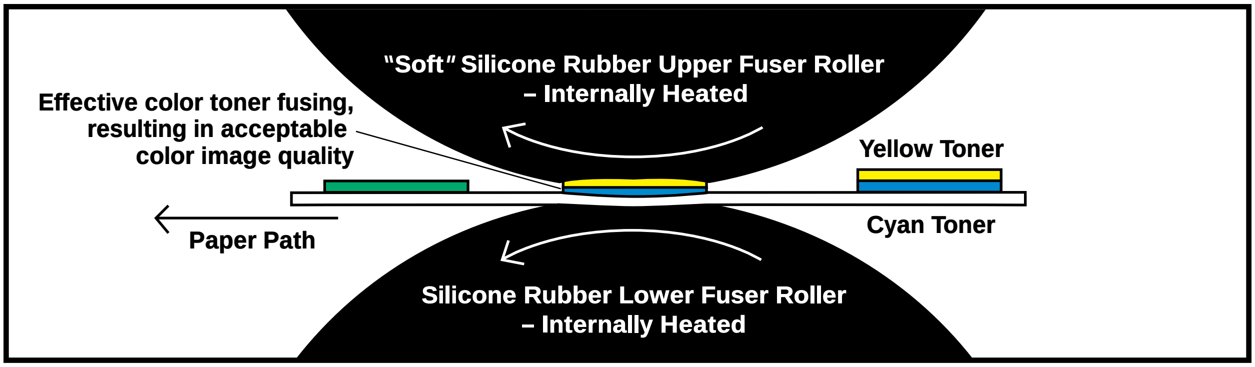


Figure 18b. Simultaneous, bi-directional fusing of color toners with soft (silicone rubber) fuser rollers enables proper blending of the color toner layers and prevents "toner shear." (**NOTE:** Illustration not drawn to scale. Distance between upper and lower rollers is inserted for illustration purposes only; upper and lower rollers are actually in contact.)

These essential advantages of silicone rubber fuser rollers do not come without corresponding "tradeoffs," in comparison to hard fluoropolymer-coated fuser rollers, however. **Current-technology silicone rubber fuser rollers provide substantially less abrasion-resistance and inferior nonstick characteristics vs. current- technology fluoropolymer-coated fuser rollers.** To compensate for these differences, unique, extensive silicone oil lubrication systems are necessary in color DC/Ps. To minimize hot toner offsetting to the upper fuser roller surface, and also help prevent surface damage to fuser roller surfaces, **color DC/P fuser rollers are continuously coated with substantial amounts of silicone oil.** Figure 19 shows a "typical" silicone oil reservoir/bath system designed for this purpose.

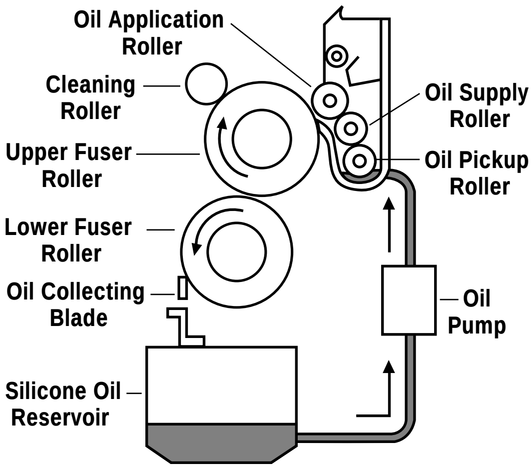


Figure 19. Silicone Oil Reservoir/Bath System

A color DC/P with such a reservoir/bath lubrication system can consume up to six liters of silicone fuser oil while producing 10,000 copies/prints. In contrast, an oil-impregnated cleaning roller, web supply roller, or "tank-type" fuser cleaning roller can provide sufficient parts lubrication in an analog copier or black-and-white DC/P with only a very small fraction of this amount of silicone oil. In fact, some analog copiers and black-and-white DC/Ps use no silicone oil at all, which clearly demonstrates how much more critical thorough, consistent fuser roller lubrication is in a color DC/P fusing system.

Internal heating of both fuser rollers is essential to proper heat transfer, and continuous coating of these rollers with silicone oil is essential to sufficient lubrication for effective toner release. However, the combination of these factors places significant material stress on color DC/P fuser rollers as well. One common failure mode –in addition to silicone oil lines on copies/prints caused by surface damage to the soft silicone fuser roller surfaces– is swelling and subsequent "de-bonding" of the silicone rubber coating layers. For example, if silicone oil penetrates ("seeps") beneath the surface of the outermost coating layer, it can lead to oil absorption into the silicone rubber base material, which swells and causes nip width distortion and poor copy quality. Oil absorption may also lead to catastrophic failure of the fuser roller due to the silicone rubber base layer separating from the aluminum insert.

Due to all these factors, plus the high image-quality expectations common among color DC/P end-users, **recommended life for color DC/P fuser rollers is typically much shorter than for the upper fuser and lower pressure rollers in analog copiers and black-and-white DC/Ps. In addition, changes in the material characteristics of the color DC/P fuser rollers during life make it essential, in most cases, that both the upper and lower fuser rollers be replaced at the same time—**even in most cases of a premature failure of one fuser roller or the other. This is necessary to ensure that the proper amounts of heat and pressure necessary to achieve simultaneous, bi-directional color toner fusing are maintained, resulting in consistently acceptable color image quality on copies/prints.

Color DC/P Toner Requirements

All current-generation color DC/Ps (including Canon-manufactured color DC/Ps) utilize dual component development systems. In addition, all toners used in current color DC/Ps are based on polyester resins, primarily because the physical properties of polyester resins allow them to physically blend together more readily and thoroughly than styrene acrylic resins. Although polyester resins are, generally speaking, more expensive to manufacture than styrene acrylic resins, the specialized requirements of color DC/Ps necessitate their use.

Polyester resin color toners are composed of the same basic ingredients as polyester resin black toner. However, black toner contains carbon black, whereas the other color (MCY) toners derive their unique colors from pigment-based colorants. Each color toner has slightly different electrical characteristics than the others, with the greatest difference being between black toner and any of the other (MCY) toners. Consequently, each color toner is compatible only with a specific, corresponding developer of its own, and color DC/Ps must have separate cyan, magenta, yellow, and black developers as well as toners.

All current-generation color DC/Ps require microfine toners (toners with an average standard particle size by volume of 7 – 10 microns). Microfine particle size is critical not only to ensuring accurate color reproduction and high-quality image resolution (by enabling the deposit of a sufficient number of toner particles within each "dot"), but in preventing the triboelectric "over-charging" or "under-charging" of toner particles. An abundance of too-small, over-charged particles can result in reduced image density and reduced developer life. In contrast, an abundance of too-large, under-charged particles can result in increased background levels, dark copies, reduced toner yields, and toner dusting within the color DC/P.

All these factors combine to make the manufacture of (color, including black) toners for color DC/Ps more costly than the manufacture of black toner for analog copiers or black-and-white DC/Ps. The raw materials in polyester resins are more expensive than those in styrene acrylic resins. The production of microfine toner particles (either black or color) is more time-consuming, and the manufacturing yields (the amount of "in-specification" toner produced per kilogram of raw material) are lower than when standard-size particles are required. In addition, because there is less total demand for color toners, they must be manufactured in relatively small batches, eliminating the "economies of scale" that a manufacturer can often realize when producing black toner typically used in analog copiers or black-and-white DC/Ps.

Toner yields for color DC/Ps are very difficult to estimate, and it is thus difficult to compare toner yields stated by different OEMs. OEMs use different measurement standards to establish stated toner yields, and the amount of toner consumed varies greatly, depending on the percentage of image coverage and composition of copies/prints produced on the color DC/P. For obvious reasons, toner consumption is significantly higher in color DC/Ps than in black-and-white copiers, especially when copying/printing high-image-coverage documents. It typically takes four different toners to reproduce a full-process color image in a color DC/P, whereas a black-and-white DC/P uses only black toner.

It is worth noting that –in corporate environments– color DC/Ps typically consume black toner about twice as fast as they consume the other color toners, primarily because these machines are relied upon to produce significant quantities of black-and-white copies/prints in these environments. Another factor to consider, especially in "print-for-pay" environments, is that many end-users are making full color copies of photographs and other high-density images, significantly increasing the average amount of toner consumed per copy.

Color DC/P OPC Drum Requirements

Color DC/Ps are designed to utilize essentially the same type of "digital" OPC drums as black-and-white DC/Ps. (**NOTE:** To minimize surface abrasion and extend drum life, Canon uses a fluoropolymer "overcoat" and/or dispersed nonstick fluoropolymer particles within the outermost charge transport layers (CTLs) of its color digital OPC drums. This is also true of the CTLs of some Canon 30mm-diameter OPC drums for use in black-and-white DC/Ps.) These digital OPC drums must provide uniform, consistent performance at a level beyond that required of OPC drums for analog copiers. Chemical ingredients must be extremely pure and substrates must be very clean compared to the materials used to manufacture some analog OPC drums. Minor defects that might be acceptable to end-users in an analog OPC drum can cause unacceptable image quality problems in a color DC/P or a black-and-white DC/P.

Some members of the office equipment and printer dealer/distributor community affectionately refers to color DC/Ps as parts-and-service "pigs," because OPC drums, toner/developer, upper and lower fuser rollers, transfer sheets, and various spare parts must be replaced or replenished so frequently. Because a typical color DC/P must complete a full xerographic process cycle (up to the fusing step) for each color of toner used, the OPC drum must complete four times as many rotations per single (full-process color) copy/print, vs. a same-diameter OPC drum operating in a black-and-white DC/P. More drum rotations per copy directly results in reduced drum life (when measured by the number of copies/prints produced).

Another factor that reduces drum life is the shorter average run lengths (ARLs) typically experienced with color DC/Ps. Because color DC/P users produce a higher percentage of single copies/prints than do users of analog copiers and black-and-white DC/Ps, ARLs for color DC/Ps are typically much shorter, resulting in a higher average number of OPC rotations per copy/print. Whenever a new copy run begins, the copier initiates a start-up cycle that creates an extreme increase in OPC rotational torque (referred to as Initial Rotations or INTR). Additionally, regardless of the length of the run, the OPC continues rotating a short time after the specified number of copies are produced (referred to as Last Rotations or LSTR).

Because of INTR and LSTR, the OPC drum completes many more rotations than the actual number of copies/prints produced, and every additional rotation contributes to drum wear. When spread over long copy runs, the number of "extra" rotations per copy remains low and the impact on OPC drum life is minimal. However, when these additional rotations are added to frequent, numerous short copy/print runs (which are typical with color DC/Ps), the average number of OPC drum rotations per copy/print is much higher and can significantly reduce drum life.

As emphasized throughout this document, color DC/P end-users are very demanding in terms of image quality and machine reliability. With this in mind, **many dealers replace color DC/P OPC drums (and some key parts) when they reach their stated life, purely as a preventive maintenance measure.** Some service technician/engineers may even replace developers well before they reach their OEM-stated yields if they encounter image quality problems. In contrast, OPC drums in black-and-white copier/printers are often not replaced as a preventive measure, but instead are allowed to run well beyond their OEM-stated life. This is yet another reason that average actual drum life is shorter in color DC/Ps than it is in analog copiers or black-and-white DC/Ps.

Another color DC/P design factor that can adversely affect OPC drum performance and/or life is the large amount of silicone oil required for fuser station parts lubrication. During the fusing process, silicone oil that is vaporized by the heat of the fuser station can adhere to the drum (and various parts). These silicone oil vapors may eventually produce a film that covers the OPC drum surface, resulting in blurry copies/prints and other image quality problems. Also, silicone oil contamination of corona wires can form silicon dioxide, a glass-like substance that acts as an electrical insulator, reducing their charging efficiency and leading to image quality problems, including white streaks, lines, and/or spots on copies.

Paper Quality and the Use of Alternative Media such as Transparency Material

Using smooth, bright, high-quality "laser" paper is essential for color DC/P end-users trying to achieve optimum color image quality. Standard bond quality paper is more porous and allows toner to settle into paper fiber crevices, creating uneven toner layers before they are properly blended. Conversely, higher-quality paper is less porous; enabling the toners to be properly layered on the top surface of the paper before being fused into the paper. In addition, high-quality paper enhances image quality by providing a higher "apparent brightness" and greater contrast between colors in images, enabling these colors to appear more "brilliant."

Paper quality can also significantly impact color DC/P parts performance and life. Several years ago dealers and distributors encountered numerous problems stemming from paper manufacturers' widespread change from acid-based to alkaline-based papers. Increased paper dusting and inconsistent electrical characteristics caused many component failures, resulting in emergency service calls. Although today's xerographic paper is much more stable than earlier alkaline-based papers, the use of lesser-quality paper in color DC/Ps can still impair the performance and/or reduce the life of many key components, including the OPC drum, fuser rollers, transfer sheets, and feed components.

Although necessary to ensure optimum image quality and outstanding performance, higher-quality paper is more expensive—yet another reason why color DC/P operation is significantly more expensive than black-and-white analog copier or DC/P operation.

A typical analog copier or black-and-white DC/P produces the vast majority of its page volume on standard xerographic (or other very common) bond paper. In contrast, it is common for color DC/Ps to produce output on other media types, ranging from overhead transparencies to "iron-on" decals.

The use of different media types can cause isolated problems or account for processes that are unique to individual color DC/P models. In some color DC/Ps, for instance, the machine slows down or the temperature is automatically adjusted when copying/printing to transparency material. With other models, no such machine adjustments are made.

Generally speaking, the greater the range and variety of media types being used in a color DC/P, the greater the likelihood of performance problems—ranging from jamming of paper and other media, to excessive wear and premature failure of critical fuser station parts. This wider variety of media being used in color DC/Ps is yet another major factor contributing to their high replacement/replenishment rates for parts and supplies.

Additional Color DC/P Service Considerations and Requirements

In addition to color DC/Ps' relatively high purchase prices and the high costs of color DC/P supplies, service costs for these machines are significantly higher than dealers experience for black-and-white copiers. Most OEMs have set comparatively low PM cycles for their color DC/Ps, in part because the yields/lives of toner, developer, and OPC drums tend to be much shorter than those used in black-and-white machines. This practice also helps ensure that technicians are inspecting and cleaning critical color DC/P parts significantly more frequently than they inspect and clean analog copier parts, for example.

Most color DC/Ps are very sensitive to extreme environmental conditions/fluctuations. Some have considerable difficulty handling paper effectively in extreme low-humidity or high-humidity environments, which has led to the inclusion of humidity control systems within these machines. Image quality can also be adversely affected in low- or high-humidity environments, because some color toners may not develop correctly under such conditions. Some color DC/Ps can compensate automatically by adjusting the transfer corona charge or other system functions, and the end-user can make manual auto-gradation adjustments using the control panel to compensate. In some cases, however, a service call is required to make adjustments to the color processing system in order to achieve acceptable color DC/P performance under adverse environmental conditions.

On average, color DC/Ps require two-to-three times more unscheduled service calls than do black-and-white copiers. **Also, service calls on color DC/Ps typically take longer to complete than calls on black-and-white machines, due to the color machines' overall complexity and the tendency for color DC/P end-users to be especially demanding in terms of image quality.** Because these calls are so time-consuming, a service technician/engineer dedicated to color DC/Ps may make only three service calls per day, on average (compared to an average of six for a service technician/engineer responsible for other equipment types). Finally, the service technicians/engineers that work on color DC/Ps must receive the highest level of training—classes are typically longer in duration and are more complicated than those for analog copier or black-and-white DC/P training, commensurate with the complexity of the equipment. Typically, these technicians/engineers are the most experienced, capable, and reliable ones available. As a result, color DC/P service technicians/engineers also require the highest compensation.

Summary

While color DC/Ps offer end-users many advantages over analog copiers and black-and-white DC/Ps, they are extremely expensive to purchase, connect to a network, service, and operate (due to very high OEM supplies costs). All these factors make it extremely important for dealers/distributors to reduce color DC/P parts-and-supplies costs wherever possible. At the same time, end-user customers are extremely demanding regarding the image quality produced by their color DC/Ps, so aftermarket parts and supplies purchased for them must provide OEM-equivalent or better performance and life.

When dealers/distributors purchase color DC/P parts and supplies from Katun, they can count on receiving the OEM-equivalent or better performance they need to keep demanding color DC/P end-user customers satisfied, while simultaneously reducing overall parts, supplies, and service costs. This can be an excellent, reliable means of increasing the profitability of color DC/Ps, which are extremely important products for many dealers/distributors.